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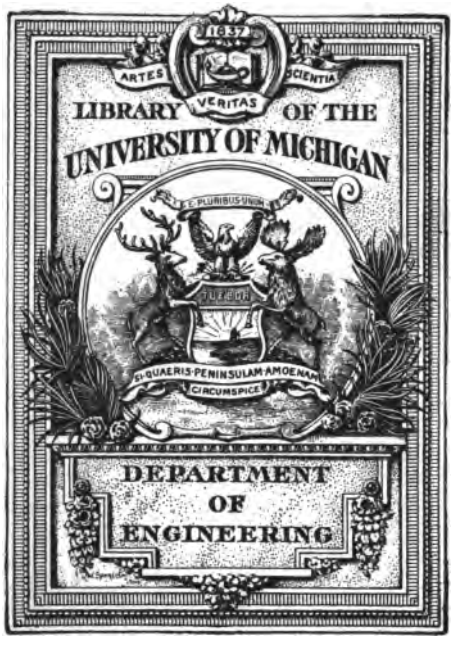
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UNITED STATES

COAST AND GEODETIC SURVEY

T. C. MENDENHALL

SUPERINTENDENT

TOPOGRAPHY

PROCEEDINGS

OF THE

TOPOGRAPHICAL CONFERENCE

108989

HELD AT

WASHINGTON, D. C.,

JANUARY 18 TO MARCH 7, 1892.

APPENDIX No. 16—REPORT FOR 1891

WASHINGTON

GOVERNMENT PRINTING OFFICE

1892

UNITED STATES COAST AND GEODETIC SURVEY

APPENDIX No. 16—REPORT FOR 1891—PART II

PROCEEDINGS OF THE TOPOGRAPHICAL CONFERENCE HELD AT WASHINGTON, D. C., JANUARY 18 TO MARCH 7, 1892

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APPENDIX No. 16—REPORT FOR 1892.

PROCEEDINGS OF THE TOPOGRAPHICAL CONFERENCE.

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APPENDIX NO. 16—1891.

REPORT OF THE TOPOGRAPHICAL CONFERENCE, CONVENED AT WASHINGTON BY DIRECTION OF THE SUPERINTENDENT IN JANUARY, 1892.

The members of the Topographical Conference, convened under instructions of the Superintendent of the Coast and Geodetic Survey, present the following report of their proceedings and submit a series of appended papers embodying the facts and reasons which have governed them in forming opinions and coming to conclusions on the subjects referred to them.

The Conference met at the Office of the Survey in Washington, on January 18, 1892, and held daily sessions after that date up to March 7, during which time the subjects assigned to committee investigation and discussed in Conference have received consideration and have been acted upon with careful deliberation.

Before taking up special questions, however, it seems important to consider the subject of surveys in the abstract, and not to lose sight of the fact that the business of making and extending them over large areas of territory is not one in the general market of professional competition, and is work seldom undertaken except under National or State auspices. Even in the most general way it is an operation of much magnitude to go over the ground of a large territory. The question of opportunity becomes, therefore, an important factor in determining what shall be the scope and character of a survey. This is apart from the question of "Special Purpose," discussed more fully elsewhere in this report.

The term "cheap survey," unless specially defined, is a misleading one to the general public. There are, of course, in topographical surveys and their resulting maps, as in other works, degrees of value. The enterprises of the day call for reliable information on all practical subjects; and topographical surveys and maps that do not meet these public requirements fail in a respect which is becoming more and more important in the economy of modern improvements. A small percentage of increased expenditure of time and means, *while on the ground*, would secure such results as the true elevation of important lakes and

ponds in their relation to the adjacent country, and the descending grades of streams possibly available for manufacturing power and other incidental purposes of utility. But where only a picture of nature is attempted, and that but crudely, and where the scale of its representation is so small that nothing very definite can be shown, the undertaking of such a project becomes one of questionable economy and expediency, unless it be of some unexplored or comparatively valueless region, or for the purpose of merely geographical maps.

The Conference desires to express emphatic disapproval of any system of field work which permits illustrations beyond the supervision of the topographer, and by which imperfect and inaccurate representations of features professed to be indicated are incorporated with its results as determinations. No such work should be regarded or accepted by the profession as a legitimate topographical survey; nor by those who recognize the importance of what, in the more highly developed countries of Europe, is considered an absolute necessity, viz, the surveying and mapping, with trustworthy accuracy, the public domain.

The members of the Conference were Assistants Henry L. Whiting, R. M. Bache, Augustus F. Rodgers, W. H. Dennis, Cleveland Rockwell, John W. Donn, C. T. Iardella, Herbert G. Ogden, D. B. Wainwright, W. C. Hodgkins, and J. A. Flemer.

Through answers to a circular letter of invitation from the Conference to contribute views on topographical matters, the following named assistants of the Survey became to that extent its coadjutors: Messrs. George Davidson, H. L. Marindin, J. J. Gilbert, F. W. Perkins, E. F. Dickins, W. I. Vinal, and Fremont Morse. To these, as having also sent answers to the same circular letter, may be added Messrs. Charles Junken, A. Lindenkohl, and F. C. Donn, draughtsmen in the Office of the Survey. For these letters see Supplement A.

The following abstract of the proceedings of the Conference records them, as far as possible, in the order in which they occurred.

The Topographical Conference having been called to order on January 18, 1892, with the Superintendent of the Survey, Dr. T. C. Mendenhall, in the chair, he suggested some of the topics which he wished discussed by the Conference.

The Superintendent, upon the close of his address, designated Mr. Henry L. Whiting as chairman of the Conference, and Mr. J. A. Flemer as secretary. The Conference itself, later in the proceedings, appointed Mr. Augustus F. Rodgers, chairman of the committee of the whole.

The duties of the Topographical Conference gradually found their preliminary place in the work of the following committees, the respective resolutions as to whose guidance, coupled with the results reached and presented in each case to the Conference, will be subsequently dealt with.

COMMITTEES OF THE TOPOGRAPHICAL CONFERENCE.

(1) Classification of topography of the United States—Messrs. Ogden, Bache, and Donn.

(2) Merits and defects of topographical instruments—Messrs. Rodgers, Donn, and Ogden.

(3) Classification of topographical field-work—Committee of the Whole.

(4) Methods of United States and Foreign Government surveys—Messrs. Dennis, Donn, Wainwright, Hodgkins, and Flemer.

(5) Uniformity in conventional signs—Messrs. Dennis, Bache, Rockwell, Donn, and Flemer.

(6) Section 4, Superintendent's suggestions—Committee of the Whole.

(7) On rules to govern the topographical surveys in the different typical sections considered—Messrs. Rockwell, Wainwright, and Hodgkins.

(8) Definition of topographical reconnaissance—Messrs. Ogden, Bache, and Donn.

The above list does not represent the order of resolutions by which committees were appointed, some resolutions not necessitating the formation of committees and other resolutions producing only transient ones.

Mention of certain committees is properly omitted from the list because their work was merely preparatory. Such are: The original No. 7 resolution and committee on rules and order of business—Messrs. Rodgers, Wainwright, and Hodgkins; the original No. 16 resolution and committee on list of topographers—Messrs. Iardella and Wainwright, and the original No. 19 resolution and committee on printing and typewriting—Messrs. Bache, Wainwright, and Hodgkins. These committees may evidently, for the reason assigned, be left out of consideration on a list of those including more permanent duty in connection with the Topographical Conference.

There is, however, a notable exception to this rule of excluding mention of committee work which has been merely preparatory, and that is to be found in the original No. 3 resolution and committee "On the Superintendent's suggestions," Messrs. Donn, Dennis, and Flemer.

This committee formulated, more precisely than they had at first been set down, the statements of the Superintendent in his opening address before the Topographical Conference. Upon that precision depended the worth of the results obtainable by the Conference through discussion. It thus becomes necessary to mention here not only the work of that committee, but to add the following summary of the statements of the Superintendent, as presented by the committee to the Conference.

SUGGESTIONS BY THE SUPERINTENDENT OF TOPICS FOR DISCUSSION.

(1) Review the present state of the science and art of topography, including the investigation of work done in our own country—
   (*a*) By the Government.
   (*b*) By private individuals.
   Also the more recent advances in methods or improvements in instruments in other countries.
(2) Classification or gradation of topographical surveys and the designation of such classes to grades, so that the character of any piece of work may be expressed with reasonable accuracy by a single word, letter, or denomination. This will include a discrimination between a survey and a reconnaissance.
(3) The establishment of uniformity in the use of conventional signs and the use of contours for the representation of characteristic features.
(4) Methods by which work may be rendered more rapid and less expensive, without material loss of accuracy, and methods for cheap topography, securing the highest accuracy attainable with the least expenditure of time and of a given sum of money.

On January 19, at the second session of the Conference, Mr. Bache read, by its request, at the instance of Mr. Ogden, a paper regarded by the Conference as relevant to the last quoted suggestion of the Superintendent. This paper was entitled "The Topography of the Coast and Geodetic Survey, with relation to its Birth, Development, and further possible Differentiation, with a Contribution thereto of a Description of a Practicable Method of Balloon Surveying." This paper is given in full as Supplement B.

We may now, to advantage, proceed to the consideration, in regular order, of the subjects contained in the preceding list of committees; for although the order of reports and discharges of committees does not necessarily conform to that order, the fact is of no moment to the clear presentation and comprehension of the various questions involved. Similarly, the interpolation by the Superintendent of other matter for consideration, during the course of the work of the previously mentioned committees, does not interfere with nor obscure the statement of their results.

ABSTRACTS OF THE REPORTS OF THE COMMITTEES.

Committee No. 1.—Classification of topography of the United States.—Messrs. Ogden, Bache, and Donn.

Resolution presented by Mr. Ogden, under which the committee acted:

That the Chairman appoint a committee of three to report to the Conference a classification of the United States, to be used as units in describing topographical work.

Abstracts of the reports of the committees.

The committee having, first of all, divided the whole area of the United States into two sections—the coast and the interior—then selected in each of these, eight typical sections susceptible, in a general way, of independent topographical treatment, considering the respective types and the character and amount of cultural detail; these two elements together properly indicating approximate scale for surveys and their approximate cost per square mile for particular regions, and reported the following classification:

Coast.—St. Croix River to Delaware Bay (New England System); Delaware Bay to Winyah Bay (Bay System); Winyah Bay to St. Johns River (Bay System); Mississippi Delta (Delta System); Texas (Texas System); Southern California (Pacific Coast System); Northern California (Pacific Coast System); Oregon and Washington (Pacific Coast System).

Interior.—Rolling lands, like New England, etc. (Primary System); Flat lands, like Southern New Jersey, Delaware, etc. (Coastal Plain System); Prairie lands, like Ohio, Indiana, and Illinois (Prairie System); Great Plains of the West (Great Plain System); Plateau Regions of Kentucky and Tennessee (Plateau System); Appalachian Mountains (Appalachian System); Rocky Mountains (Rocky Mountain System); Sierra Nevada Mountains (Southern half, Rocky Mountain System; northern half, including the Cascade Range, Apalachian System).

The report from which the above is taken will be found in Supplement C.

Upon this Committee, No. 1, was also imposed the duty of reporting upon instrumental methods and cost of surveys per square mile referred to hereinafter under Committee No. 3.

Committee No. 2.—Merits and defects of topographical instruments—Messrs. Rodgers, Donn, and Ogden.

Resolution presented by Mr. Rodgers, under which the Committee acted:

That the chairman appoint a committee to examine and report upon merits and defects of instruments in use, and to suggest improvements, if any are deemed necessary, to make topographical instruments more portable and effective.

The appointment of this committee led at once to a thorough examination of the topographical instruments of the Coast and Geodetic Survey by the members of the committee, and to an informal visit by them, for the purpose of examining such instruments, to the Office of the Geological Survey.

The report of the committee indicated the advisability of essaying, in the interests of portability, the introduction of the so-called aluminum bronze in the manufacture of topographical instruments.

Various possible improvements were suggested by the committee with reference to the movement of the plane table and to the alidade. It expressed the desirability of placing the vertical arc of the alidade in a different quadrant of the circle from that which it occupies at present, with the graduation on the edge of the arc, so that in the ordinary position of the observer, aligned with the telescope tube, at its eyepiece, he can, without moving, read the graduation on the arc.

The committee also recommended that, in addition to the usual horizontal lines in the alidade telescope for telemeter measurements, two intermediate half lines be introduced on each side of the middle line for the purpose of enabling the observer to double the distance of determination. It makes mention of the boat telemeter, of Mr. Bache's invention, used for submerged shores of sedge grass, etc.; also of the aneroid barometer, of latest construction, for mountain work; of the distance measure of Oertel & Son; of the odometer, for small scale work, if a reliable form can be found; of the tachygraphometer, if found available upon careful experiment; of the Meissner level, and of an automatic gravity level, if a satisfactory form can be devised.

The committee recommended that the Superintendent be requested to appoint a committee of officers of field experience to determine upon the best kind of paper for field work, and the best adhesive substance, woven fabric, and methods in connection with backing plane-table sheets.

The investigations of the committee were directed to the employment of an alloy of aluminum solely with the view of securing lightness and portability.

A supplemental report of the committee, however, states that aluminum would not be suitable for the rules of alidades. The full report of the committee is given in Supplement D.

Committee No. 3.—Classification of topographical field work—committee of the whole.

Resolution, presented by Mr. Ogden, under which the committee acted:

That a report to the Conference upon a detailed classification of topographical field work, to be based upon the previously ascertained relations (by the committee appointed for the purpose) of the relative difficulties of different regions of the United States, be prepared by the committee of the whole.

This question was afterwards considered by two committees, Messrs. Rockwell, Wainwright, and Hodgkins forming one, and Messrs. Ogden Bache, and Donn the other.

The first of these committees is known as that "on rules to govern topographical surveys in the different typical sections considered."

The second was Committee (as per preceding list) No. 1, which considered the subject of "Instrumental Methods and relative Cost of surveys per square mile," under the resolution of Mr. Bache, as follows:

That a committee be appointed to report on instrumental methods by means of which can be produced, with the necessary trigonometrical basis, topography of the greatest accuracy compatible with a very limited expense of time and money, and to estimate, with reference to different types of country, assuming a scale for each of these types, the relative cost per square mile (of specific type and scale) of the aforesaid triangulation and topography.

Under the auspices of the committee of the whole, sitting on the question of classification of topographical field work, also appears a statement of "Scales of Topographical Surveys of Europe and America."

Abstracts of the reports of the committees.

A paper presented by Mr. Rodgers was entitled "Facts and Possibilities in Topographical Work."

(For Mr. Rockwell's report from the first committee, as finally adopted by the Conference, see Supplement E.)

(For Mr. Donn's report, acting as secretary for the second committee, see Supplement F.)

(For the paper by Mr. Rodgers see Supplement G.)

(For the statement on "Scales of Surveys" see Supplement H.)

Committee No. 4.—Methods of United States and Foreign Government Surveys—Messrs. Dennis, Donn, Wainwright, Hodgkins, and Flemer.

Resolution, presented by Mr. Dennis, under which the committee acted:

That a committee of five (5) be appointed by the chairman to report on the methods of making topographical surveys by the several departments of the United States and Foreign Governments, and to recommend such changes or improved methods, if any, as they may deem of advantage to the work, as now executed by the U. S. Coast and Geodetic Survey.

The report of the committee under the above resolution is necessarily quite voluminous. It consists, first of all, of a paper in the nature of a preamble, by the chairman, Mr. Dennis. In this he concludes by quoting an interesting passage from a contribution on cartography sent to the board by Mr. A. Lindenkohl, on the subject of using the same unit of measure for heights and distances; secondly, of a paper by Mr. Donn, "On critical surveys for special purposes in the United States;" thirdly, of three papers by Mr. Wainwright, "On topographical surveys in the United States," "On the methods of the Coast and Geodetic Survey," and "On topographical surveys in Italy;" fourthly, of two papers by Mr. Hodgkins, "On surveys in England and France," and "Extracts from the report on European topographical maps, by General Derrécagaix, 1889, on Belgium, Denmark, Holland, Portugal, Roumania, Russia, Spain, Sweden, and Norway;" fifthly, of a paper by Mr. Flemer, "On surveys in Germany, Austria, and Switzerland." The investigations by this committee do not develop any methods of work that could be advantageously substituted for those now used in the operations of the Survey.

Two subjects, not having any direct connection with the labors of this committee, arising from the resolution under which it was formed, were placed in the hands of the committee by the Conference—photogrammetry and the method of balloon surveying, suggested by Mr. Bache.

The first of these subjects is presented in an appended paper by Mr. Flemer, entitled "A short historical review of the art of photogrammetry."

A subcommittee of this committee No. 4, consisting of Messrs. Donn, Wainwright, and Hodgkins, was appointed by the chairman to test the value of this method by experiments in the field. It having proved

impracticable to complete these experiments during the session of the Conference, a resolution was passed requesting the Superintendent to authorize their completion after its close.

The second subject is considered in a special report on Mr. Bache's plan for balloon surveying.

(For all these reports, see Supplement I.)

Committee No. 5.—Uniformity in conventional signs—Messrs. Dennis, Bache, Rockwell, Donn, and Flemer.

Resolution, presented by Mr. Rodgers, under which the committee acted.

That section 3 of the Superintendent's suggestions, viz: "Establishment of uniformity in the use of conventional signs," be referred to a committee of five (5) members, to be appointed by the chairman.

The conventional signs referred to relate more particularly to the original than to the published charts of the Survey. As indicated above, by the suggestions of the Superintendent and by the terms of this resolution, the intention was to secure uniformity in the practice of the Survey. But it must not be inferred from this circumstance that the graphical methods of the Survey have ever been lax. The contrary is the fact, both as to the office and the field. But whereas it is easy to secure for the office, where persons are working in close quarters, perfect uniformity in this matter, the case becomes very different where persons are scattered over so vast an area as that of the United States. So, while great uniformity has always obtained, even in the latter case on the Survey, the present endeavor is to be more accurately stated as in the interest of securing for the field still greater uniformity than heretofore in the use of conventional signs on original charts.

From the nature of the subject placed before this committee no formal report in writing was necessary.

The procedure adopted by the committee was to take as a basis the whole range of conventional signs heretofore used on the Survey, cancelling some of them, adding some, and modifying others. The list, as modified in committee, and then finally perfected by the action of the Conference, became the new one, exhibited in Supplement J. (Illustrations 27, 28, 29, and 30.)

Committee No. 6.—Section 4, Superintendent's suggestions—committee of the whole.

Resolution, presented by Mr. Donn, under which the committee of the whole acted:

That the consideration of section 4, viz: "Methods by which work may be rendered more rapid and less expensive," be referred to the committee of the whole.

The conclusions on this subject, first of all discussed in a general way by the Conference, are embodied in the reports of the committee on the "Classification of the Topography of the United States," of which Mr. Ogden was chairman; on the committee on "Rules to govern Topographical Surveys in the different typical sections consid-

ered," of which Mr. Rockwell was chairman; of the committee on "Instrumental methods and relative cost of surveys per square mile," of which Mr. Ogden was chairman; and of the committee which furnished a table of the estimated relative cost of surveys per square mile in typical sections on specified scales, of which Mr. Rodgers was chairman.

The work of the first three of these committees, already mentioned in connection with them, and the work of the last one, whose report will be found in Supplement C, cover the general scope of the matter submitted to the Conference under section 4 of the "Suggestions of the Superintendent."

In other words, these four reports mentioned cover in a general way the requirements submitted by the Superintendent as to "Devising methods by which work may be rendered more rapid and less expensive without material loss of accuracy, and methods for cheap topography, securing the highest accuracy attainable with the least expenditure of time and a given sum of money."

Committee No. 7.—On rules to govern topographical surveys in the different typical sections considered—Messrs. Rockwell, Wainwright, and Hodgkins.

This is the committee mentioned in the second paragraph of this report relating to committee 3 of the list, where its work was spoken of in connection with that of another committee, because the work of the two together covered the resolution requiring "Classification of topographical field work, to be based upon previously ascertained relations of the difficulties of different regions of the United States." (See, as before, Supplement E.)

Committee No. 8.—Definition of topographical reconnaissance—Messrs. Ogden, Bache, and Donn.

This committee, having considered the question above indicated, finally presented the following definition, which proved acceptable to the board:

> Topographical reconnaissance is a determination of the topographical features of a region or locality that, if plotted, would represent on a map only a partial development of the salient features of the region.

Upon the appointment of the committee on instruments, Messrs. Rodgers, Donn, and Ogden, these gentlemen, with other members of the board, under a previous informal invitation to that effect, visited the Office of the Geological Survey, with the object of examining any instruments that might prove novel and of utility in any work of the Coast and Geodetic Survey. This visit, according to the report of the members of the committee on instruments, proved so interesting that another group of members of the Topographical Conference took advantage of a general informal understanding to the effect that the officers of the Geological Survey would be pleased at any time to have members of the Conference pay them a visit and examine into such

details as might interest them at the Office of the Geological Survey, and, under the guidance of Messrs. Gannett and Wilson of that Survey, obtained valuable insight into its topographical methods and instruments.

At that time the members of the Topographical Conference had reciprocated the courtesy shown them by the officers of the Geological Survey, and had extended to them, in turn, an informal invitation to visit the Office of the Coast and Geodetic Survey, and it was decided to anticipate the informal return of the visit of the members of the Conference by a formal invitation to their previous entertainers to visit the Conference in session at the Office of the Coast and Geodetic Survey.

To that effect the following resolution, drawn up by Mr. Bache, was passed by the Conference:

Resolved, That the Topographical Conference, convened at the Office of the Coast and Geodetic Survey, by direction of the Superintendent, and having under consideration the general subject of Topography in the United States and foreign countries with reference to methods employed in the execution of that branch of surveying, their merits and their expense, would be pleased to invite the Director of the Geological Survey to delegate such members of his corps as he may wish to select to meet the said Conference at the Office of the Coast and Geodetic Survey, for the purpose of bringing about a useful interchange of experience and views on this subject of interest common to both Surveys.

This resolution, passed February 11, was sent by the chairman of the Conference, with a transmitting letter, to the Superintendent of the Coast and Geodetic Survey, requesting him to forward it to the Director of the Geological Survey.

On February 13 the Superintendent addressed the Conference, expressing his gratification at the action involved in the passage of the resolution above quoted, and his belief that the interchange of views there alluded to would be beneficial for the co-ordinate surveying branches of the Government service.

On February 16, the Conference having been notified that, in response to the invitation conveyed in the resolution, officers of the Geological Survey would present themselves at 2 p. m. of that day, prepared to receive them.

The gentlemen delegated by the Director of the Geological Survey to visit the Conference were Mr. Gannett, Mr. Wilson, Mr. Thompson, and Mr. Baker.

The members of the Conference, after receiving them, and after opening remarks by the chairman, listened to statements made in succession by their guests. After these statements on various points of professional interest had been made, conversation became general throughout the room regarding details suggested by the preceding statements. The meeting came pleasantly to an end with an expression of great mutual gratification.

Immediately upon the withdrawal of the visiting body the Conference

came formally to order, and Mr. Rodgers offered the following motion, which passed:

That a resolution of thanks to the delegates of the U. S. Geological Survey be passed by the board, and that the same be transmitted to them, through the Superintendent, to-morrow.

Under this motion Mr. Bache offered the following resolution, which passed:

Resolved, That the members of the Topographical Conference of the Coast and Geodetic Survey, now in session, express through the Superintendent of the Survey to the Director of the Geological Survey, and to the officers of that Bureau, delegated by him to visit the Conference, their gratification at the visit to-day of those gentlemen, and their fullest recognition of the valuable results accruing from this meeting for the purpose of an interchange of views as communicating to mutual advantage some of the fruits of experience of the respective Surveys.

On February 19 the chairman presented to the Conference a letter received from Mr. Gannett, setting forth the methods of topographical surveying employed on the Geological Survey in the northeastern division of the work. This letter was a response to inquiries made at the meeting above referred to, between the officers of the two Bureaus. It was read and ordered to be copied in full in the minutes of the Conference.

A paper was subsequently presented by Mr. Ogden, referring to this letter, and to the undesirability of applying the methods described to the seaboard work of the Coast and Geodetic Survey; and the opinion of the Conference on the availability of these methods for the coast work was finally expressed in the following resolution:

Resolved, That in the opinion of the Topographical Conference the methods of Topographical Surveying described by Mr. Henry Gannett, chief topographer of the U. S. Geological Survey, in his letter of February 19 to the chairman of this Conference, would not prove satisfactory and economical in surveying the narrow belt of topography along the coast, to which the work of the Coast and Geodetic Survey has been confined.

Mr. Gannett's letter and Mr. Ogden's comment will be found in Supplement K.

The minutes of the proceedings of the Topographical Conference evidenced, as to its work, that many resolutions were passed looking to improvements of various kinds. Mention of all of them would obviously be out of place in a general report but will be found in the supplements.

PRINCIPAL CONCLUSIONS FORMULATED BY THE CONFERENCE.

The following paragraphs state, in succinct form, the principal conclusions reached by the Conference:

(1) That balloon photography is not applicable for the purposes of a rapid and economical topographical survey.

(2) That the present standard for topographical work along our coasts should be maintained.

(3) Formulates rules for governing topographic work on specified scales for various typical regions, which would produce maps containing the greatest amount of information for the least expenditure of time and money. Also estimates the approximate cost per square mile for such surveys.

(4) That over a sparsely inhabited region a less elaborate survey, costing much less per square mile, could be made, which, though lacking in much desirable information, would prove useful in the development of that region.

(5) That the plane-table is unequaled in its usefulness in every order of work, and names certain other instruments which would be valuable as auxiliaries.

(6) Recommends certain improvements to the plane-table, and advises the appointment of a committee to superintend the same.

(7) That the mean sea level is the most desirable datum plane for elevations in topographical surveys.

(8) Can not recommend any method of making topographical surveys of the coasts that would be an improvement on that now in use in our own service.

(9) That photography may be found at times a useful auxiliary, but under ordinary circumstances can not compete with the plane-table in rapidity, economy, or accuracy.

(10) That the material of our plane-table sheets is susceptible of much improvement, and that the appointment of a committee to experiment in this direction is recommended.

(11) Presents a revised list of conventional signs for field use.

(12) Defines a topographical reconnaissance as "a determination of the topographic features of a region or locality that, if plotted, would represent on a map only a partial development of the salient features of the region."

(13) Recommends the adoption of the metre as the unit for vertical as well as horizontal measures.

(14) That the methods of the Geological Survey, as described by Chief Topographer Gannett, would not prove satisfactory or economical for our coast work.

(15) Recommends that a manual be prepared of all instruments in use by the Coast and Geodetic Survey.

(16) Recommends the preparation of a new table for heights, using the metre instead of the foot, as the unit for elevations. Also a new empirical formula to be devised for computing elevations.

(17) Recommends the continuance of the committee on photographic surveying, that it may conclude its investigations.

(18) That in the opinion of the Conference, topographical surveys, to subserve the greatest number of useful purposes, should not be made on a scale smaller than 1–40000.

RESOLUTIONS OF IMPORTANCE PASSED BY THE CONFERENCE TOWARD THE CLOSE OF ITS SESSIONS.

Three resolutions, passed during the last part of the sitting of the Conference, relate to matters of sufficient general interest to warrant mention of them. One of these was a recommendation to the Superintendent to appoint a permanent committee of three topographers, two of whom should be members of this Conference and one a member of the Instrument Board of the Office, looking to improvements in topographical instruments, and especially to perfecting the plane-table and field sheets. It was also recommended, through a second resolution, that, for the future, mean sea-level should be taken as the datum plane for elevations in the work of the Coast and Geodetic Survey. The third of these resolutions recommends that, for the future work of the survey, the metre be taken as a unit for heights as well as for linear measurements. Following out this last action, the Conference adopted a resolution offered by Mr. Hodgkins, asking for the preparation of a new table of heights on the metric system, and a resolution offered by Mr. Rodgers, suggesting the desirability of a new formula for the ready computation of heights without the use of tables. On the last day of the Conference Mr. Hodgkins submitted a brief and convenient formula for such purposes. (See Supplement L.)

Another important matter was contained in a resolution proposed by Mr. Hodgkins, at the suggestion of Mr. Donn, and adopted by the Conference, requesting the Superintendent to have prepared a handbook of all instruments used in the Survey, with plates and full descriptions of adjustments and methods of use.

A description of the tachymeter and tachygraphometer, translated by Mr. Hodgkins, and a plate illustrating the power of different scales for the delineation of topographical features, prepared by Mr. Donn, matters of interest in connection with the subjects discussed by the Conference, will be found in Supplements M and N.

With these last memoranda of important points, of which the Topographical Conference has taken cognizance, it closes its report in the belief that it has left little untouched in its discussions that is of much moment, and in the hope that its labors in its field of duty will not be unfavorably regarded by those who are by training best fitted to be judges of its work.

Respectfully submitted.

HENRY L. WHITING,
Chairman.
J. A. FLEMER,
Secretary.

WASHINGTON, *March 8, 1892.*

SUPPLEMENT A.

LETTERS FROM ASSISTANTS AND OTHERS, ADDRESSED TO THE CHAIRMAN OF THE CONFERENCE.

LETTER FROM ASSISTANT GEORGE DAVIDSON.

In response to your letter of January 25 I have drawn up the following memoranda in answer to your suggestions:

CLASSIFICATION OF TOPOGRAPHICAL SURVEYS.

The necessity for this was quickly appreciated on the Pacific coast, where the necessity for promptly presenting results upon an unknown coast of great extent was urgent, and where the character of the orography was altogether different from that of the Atlantic or Gulf of Mexico. In fact, I have visited the coast of no country where the physical difficulties to be overcome are so great as along this seaboard. My first serious experience in this matter was at Cape Flattery in 1852, where Mr. Lawson executed the topography under my direction. All the conditions were novel. A wild, rugged, high, rocky coast exposed to the great and ceaseless swell of the North Pacific, timbered from the edge of the cliffs to the crest line of the hills, impenetrable on account of the dense undergrowth, cut up by deep and irregular gulches, destitute of even Indian trails over any part, and impracticable for the development of a tertiary triangulation with the means at my command. The means of transportation, two canoes. Grit, endurance, and ability in the topographer, and good support from his men. We had no proper classification for the work, and no sign to indicate its character.

I represented the case to Superintendent Bache, but he was averse to changing the methods of execution or of exhibiting topographical details. In 1868 Superintendent Peirce acceded to my proposition to execute certain parts of the mountain topography in less detail than usual, and such work was done by contouring in 40 and 100 foot curves of broader generalization, and exhibited on the original sheets in broken lines or in a different colored ink. In the wild gulches and rugged heads in the seaboard only generalizations are necessary, and on the crest line of the coast mountains, which gives the navigator his landfall, only sufficient accuracy is demanded to give decided expression to the features. The same sheet should, however, exhibit with

minute accuracy all the details of the shore for a certain distance inland, and the outlying rocks.

Examples of this are given in the topography from Mendocino southward, and of the Santa Lucia Range south of Monterey.

In all this work I believe in general expression being given by contours, and that characteristic features be represented by suggestive conventional signs.

In the topography of the immediate coast line on the Pacific coast, accuracy has been the governing spirit of the work, and as the needs of navigation and of coast commerce have increased, more detailed accuracy has been demanded. Minute accuracy of the position and peculiarities of outlying rocks is essential to secure safer navigation on this seaboard, where dense and long-continuing fogs prevail, and where the coast line may not be seen from less than a mile distant for consecutive weeks. The navigator in command of a coast steamer runs by time and courses—time to minutes and courses to degrees. When his time is up and he has not made his landmark, he heads directly through the fogs toward the shore and picks it up by the rocks, and then continues along the shore carefully until he reaches a rock whose features he knows and whose accuracy of position he has practically verified. I have witnessed this method of navigation frequently.

In the earlier days the heights and forms of the rocks were not noted and many of the smaller rocks were omitted, but the experience from Point Reyes to Punta Arena, where large numbers of chutes, outreaching high wharves, flying trapezes, etc., have been constructed outside the cliffs and rocky islets, demonstrates the value of the minute survey. All these small and dangerous anchorages are approached with some confidence even in foggy weather when the Coast Survey chart locates all the notable visible as well as sunken rocks.

Improvements involving from $10,000 to $50,000 at a single one of these landing places are made upon the basis of the Coast Survey measures.

TOPOGRAPHICAL RECONNAISSANCE OF THE COAST LINE.

In 1868 I proposed to carry a topographical reconnaissance from Cape Flattery southward for the purposes of the coast pilot. The necessity for this survey increased yearly, not only for coast-pilot use, but to locate and connect the mouths of rivers and bays and give a fair outline of the immediate shore line. For a time, coast commerce got ahead of the regular work.

The results obtained by the topographical reconnaissance of 1887 and 1888 were extremely satisfactory in their results and in the smallness of cost. But in each case they were pushed with such personal vigor and ability, such tenacity of purpose and endurance of privation, that they are exhibits of what can be done in an emergency rather

than what is to be done as a regular business. Each party was pretty well "used up" after the performance of 1887.

I affirm with great earnestness and sincere pleasure that no other organized body in the service of the Government or any corporation could have produced the topographers that could have executed the topographical reconnaissance of this coast in 1887 and 1888 in the same time, with the same means, at the same cost, and with as great accuracy as the Coast Survey assistants did.

A similar topographical reconnaissance of the coast line is what will suffice in Alaska for many years, except in special localities; but it will have to be executed in a different manner and with different means and at greater cost, for the shore line is generally impassable.

Charts published from such surveys should have proper designation of the method employed.

Surveys like those of the Santa Barbara Islands have no parallel on the Atlantic coast. The surveys of the islands of Washington Sound have very many difficulties on account of the fierce character of the currents, absence of trails, the foggy weather, and still greater hindrance of smoky weather. Patience, ceaseless watching, avidity in seizing every opening, and rapidity and accuracy of execution can alone accomplish results. Similar work under similar conditions can not be executed with less cost than is done by the conscientious and able officers on that duty.

DETAILED AND MINUTE TOPOGRAPHY.

For special locations, like San Diego, San Francisco, Humboldt, Yaquina, the mouth of the Columbia, etc., the details and accuracy of the survey should be of the most minute character, and exhaust the skill of the topographer; and certain parts should be resurveyed to exhibit changes of shore line effected by natural or artificial causes.

METHODS FOR THE RAPID EXECUTION OF ACCURATE WORK AT A MINIMUM OF COST.

I have already referred to the rapidity of the topographical reconnaissance of Washington and Oregon at a minimum of cost and a maximum of exhaustion of the topographers.

For the general topography of the coast line much is necessarily left to the judgment of the topographer as to details. To locate every post of a telegraph line would be a wicked waste of means and time.

Much depends upon the facility for executing the tertiary triangulation, the number of triangulation stations, and the rapidity and accuracy of the computer.

In some cases, as in the Columbia River bottom, a great deal depends upon the state of the river (there being two freshets annually), and on the state of the low water as to what shall be taken as the shore line of an island whose upper end is well out of water and the lower end

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below the surface, with a very low grade of descent. Much depends on the condition of the atmosphere on the northern coast and in the Puget Sound region, where great fires prevail in the working season, and where I have known the shore line invisible for weeks at a ship's length. All field work must stop, and it can not be done in winter because of continuous adverse weather. This last project was tried by Superintendent Patterson and utterly failed.

Under all the conditions that have prevailed on this coast, I have known the best men, consumed by anxiety, make a weak show of triangulation and topography for the season on account of smoky weather or the prevalence of fogs and rains, or both. While at the south in the same season, all the conditions of the weather would be favorable.

When the character of the work in any locality has been decided upon, the execution must be trusted to the business management, professional ability, and conscientious execution of the officer in charge. When he knows how much money is to be allotted to him for the season he will lay out his plans to get the most out of it. We have now no one on the coast who would not strive to do so. The spirit of honorable rivalry has generally prevailed.

I have no faith in topography that is essentially "cheap."

I have not a particle of faith in any topography where it is published that one party has executed 3 000 square miles in a month.

Finally, I hardly see how the methods of topography as carried out on this coast can be essentially modified. As the survey advances into the wooded regions to the north it will be impracticable to continue the accuracy attained in an open country, and some changes will be necessarily made by each one; but whether these modifications can be formulated is a question that will solve itself. I have known no wastefulness of means, and I know the officers have a pride in the character of their work, and in the amount which they can present for the money allotted to them. It is probable that the doubling of a party of tertiary triangulation and topography will be the first means to decreasing the cost. This was done by me from 1850 onward through the Puget Sound work to 1857; and at Lola, Round Top, Mount Diablo, etc., where topographical sheets were made by the regular triangulation party. It has been done by others.

I am satisfied on one essential point, the Coast and Geodetic Survey cannot sacrifice the minutest accuracy in its methods wherever accuracy is necessary; yet in this case it is a decided advantage in getting the most good work for the least money to "double" a party.

LETTER FROM ASSISTANT HENRY L. MARINDIN.

In answer to your circular letter of January 26, 1892, I beg leave to submit the following:

What shall determine the accuracy and amount of detail to be shown on a topographical survey and, consequently, the cost of the work?

It seems obvious that the requirements for a topographical survey of New York Harbor should not be the measure of what is requisite for a survey of the Florida coast or that of the Gulf of Mexico.

The object to be subserved by the Survey, it seems to me, should determine the accuracy in details and the cost of the work, with the scale to be employed.

Heretofore in many cases the practice has been not to discriminate sufficiently in the scale to be used.

For localities on the coast of Florida and on the Gulf of Mexico scales of 1–30000 to 1–50000 would give ample room to delineate the details necessary to be shown. From this I would except the main harbors and river outlets where larger scales could be used.

For surveys of important harbors like New York, Boston, Portland, etc., the larger scale the better, and here again one is impressed by the object for which the survey is intended.

Taking for instance a survey for the location of pier lines, a smaller scale than 1–1000 should not be entertained; on such a scale the topographer can represent all the minute details so valuable to the engineer, and he can give the actual measurements made with tape or chain along the continuous wharf line expressed in the figures, to be inked in as a part of the plane table data. This requirement is urged because of the fact that a plane table survey, without actual measurements given in figures, and depending for measurements on the accuracy of a changeable scale is not received in evidence before a court of law, but if it shows actual measurements expressed in figures it at once takes its place as a legal document.

Another point to which I beg leave to call your attention is that of the plane of reference for heights and the bench marks to be established by the topographer.

From my experience in the Survey I am of the opinion that the plane of reference should be approximate mean sea level. I say approximate because with the means at his command the topographer could determine no other. High water, or high-water mark, so called, should be discarded as a plane of reference.

The high-water line, as generally defined by the "crest of the beach," is anything but a horizontal plane; its elevation varies with the locality and depends on the exposure of that part of the shore to the wind and storm waves, modified by the existence or absence of bars and shoals off shore.

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Low-water plane for reference is open to the same objections as "high-water mark," with, however, some extenuating circumstances in its favor.

Mean sea level, it would seem, is the least objectionable plane of reference. A very close approximation to mean sea level can readily be obtained by observing a single high and low water on a common tide staff, and by referring the zero of this staff to a bench (all of which can be done by levels with the plane table and alidade with striding level). The plane of reference can be preserved to be referred at some future time to a more accurate mean sea level if the necessity arises.

By noting the heights of this plane of reference on the sheet, together with a description of the bench established by the topographer, the value of the survey will be increased.

LETTER FROM ASSISTANT J. J. GILBERT.

I have just received your circular letter, and although my special attention is now for the first time directed to the objects of discussion before the Conference; and although I have been so long entirely separated from my associates in the Survey, association with whom would, doubtless, have given force and expression to opinions on these subjects which may now lie dormant in my mind; yet, as not wishing to shirk any responsibility, I will venture to make a very general response to your invitation.

On the first topic I have nothing to say; if there has anywhere been any advance in methods or improvement in instruments in the last twenty odd years, I have yet to hear of them.

On the second topic I have little to say; the extremes may well be designated as "survey" and "reconnaissance," but there are many degrees of accuracy between these extremes, owing mechanically to the scale, physically to the character of the country; or the amount of detail may depend upon the object of the survey, or be limited by the expense of time or money; these different grades of work might well be designated so as readily to distinguish them; but to express the distinction by a single word would seem difficult unless words were coined for the purpose; the use of compound words would be simpler, and following the method of distinguishing the triangulation, primary, secondary, and tertiary surveys might with use come to sound very proper.

Third. I believe that the conventional signs should be simple and uniform, but not multiform, as few as is possible. All cultivated land, except perhaps rice fields, may well be represented as grass land; all

coniferous trees by the same sign, one made by three lines crossing, thus ✳, seems more simple, and is easily formed; all deciduous trees by a common sign. I would not attempt to designate sawmills, churches, etc., by any conventional sign, but would print their names on the map. The contours as heretofore used in the Survey seem to meet every requirement, and I can conceive of no improvement.

Fourth. The value of anything has a ratio to its cost. Excellence in any line is not achieved by cheap methods. I do not believe in extravagance, but I do believe that an attempt to do work any cheaper than the conscientious assistant now does it would be unfortunate—this, of course, as to methods; in some of the circumstances of work economy might be practiced, as hiring a horse and saddle instead of team and buggy, when the former would answer every purpose, but this would apply to other classes of work as well as topography.

Now, for an actual comparison of work: Last season I made a survey of the water front of Whatcom and Fairhaven. About one-third of the shore line was very rocky and difficult. A civil engineer made a survey of the water front of Tacoma, all very easy shore line; the amount of work done in each place was approximately the same, probably a mile or two more of shore line at Tacoma; the Whatcom work was finished in six weeks, and, including my own salary, cost about $1,000, somewhat less; the Tacoma work took more than three months and cost over $3,000.

I believe it can be readily demonstrated that good work can be done as readily and cheaply by the Coast Survey method as any other, and, indeed, more rapidly and more economically. If this is true, then the remaining proposition is, shall we do cheap work for the sake of greater economy? I say most emphatically, no. What is worth doing at all is worth doing well. If there is great haste in obtaining results let that work be done quickly, and as a consequence cheaply, and let it be called, what it in truth is, a reconnaissance, and let the careful survey follow in due time.

As to securing the most work and the greatest accuracy with the least expenditure of time and money, this I believe rests mainly upon the assistant in charge of the work, and that is what we should all endeavor to do—it is to be secured by good judgment and by wasting no time.

Recurring briefly to the first topic: I have often had trouble in getting the rodman to hold his rod true, and it has occurred to me that this difficulty might be remedied by a small sight tube screwed through the rod about the height of the eye, and across the lower object end of the tube a small level, so that the rodman could always point the line of sight to the plane table, thus holding the rod perpendicular to the line of sight, while he could at the same time see the level and keep the rod from leaning to one side. Such an appliance could be cheaply made in the Office and readily attached to any rod.

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LETTER FROM ASSISTANT F. W. PERKINS.

I have your communication of the 25th. While I shall take much interest in the results of your deliberations, I am unable to contribute any suggestions for the consideration of the Conference.

I inclose, however, two letters from Mr. J. C. Olmsted, which, although relating to the cost and requirements of topographical work of a special class, may be of interest to you. These letters were written at my request some years ago when engaged in collecting information as to the cost of different classes of topographical work, a subject which was at the time interesting my friends in Rhode Island.

BROOKLINE, MASS., *February 23, 1885.*

* * * Prices of surveys (topographical) made under our direction have ranged from $2.50 to $20 or more per acre.

A well-educated surveyor, handling the instrument himself, and plotting and drawing himself, with two apprentice or cheap-waged assistants, can make a map of open or nearly open ground sufficiently accurate for preliminary estimates of earthwork and general plans of roads, etc., for an average of, say, $5. The best system is by plane-table sheets for topography, I believe, but usually, if the character of the ground admits of it, the whole area is laid out in squares of 100 feet and stakes driven, to which reference is made for location of trees, fences, rocks, and buildings, etc., and which stand till levels are taken at all of them. Ordinarily a good many other levels are taken for the better delineation of the contours—say perhaps twice as many. For our purposes levels should always be taken along existing streets, water levels, ground at doorsteps, floor levels, etc. All trees standing singly or in groups are usually located, and a few of the finest in woods, such as it would be a pity to disregard in planning, where more important considerations did not apply.

Of course it is very difficult to specify with such exactness the character of a survey as to admit of the principle of giving the work to the lowest bidder. The surveyor who lives near the work can usually do the work much cheaper than one who has to pay traveling expenses, so that if the local surveyor is not wretchedly bad and the work very large and important, we usually recommend the employment of the local man. We have had some very queer specimens of draughting and often grossly inaccurate data from such. It is usually more economical to fix upon a rate per acre or a lump sum and leave it to the surveyor to give as much time to it as he can afford to. We find that this usually results in the surveyor saying that he didn't make anything and would have to charge more next time. On the other hand, if the surveyor charges by the day with expenses he is well enough satisfied, but the owner who pays for the work is generally left feeling very sore—that is, it is very easy to make a survey cost a great deal more than the average of $5 which I have mentioned. In park work, where the work is done by hired men, the cost I should judge usually exceeds $10 per acre and sometimes $20.

I send you several lithographic reductions of surveys, which have been made expressly for our purposes. That of "Properties in Newport" cost $3 per acre, and was plotted at 100 feet to an inch. Of course at that price, with such very rough ground, the instrumental work had to be diminished and the sketching on the ground of contours and rocks increased. It has proved entirely satisfactory for its purpose of running streets through and selecting house sites, but in some cases the design has been or will have to be intelligently modified to avoid bad rock cutting and so on. Still it would have been extravagant to have paid much more for a survey for the purpose in view. Part of the streets have been built according to our plan at an average price per running foot ($1.65 including crushed stone roadbed).

The map of "Aspinwall Hill" was an unusually accurate survey, plotted at 100 feet to an inch, but I do not know what it cost.

The map of "Belle Isle" was done by contract at a round sum according to our specifications. It was plotted on sheets at 50 feet to an inch, and also on one sheet at 100 feet to an inch. On the large scale all measurements locating isolated or principal trees, buildings, wharves, etc., were shown, also levels which were taken at every 100 feet, with others where necessary. I can not remember the price paid, but it was low, I should think $1,500 or $2,000.

The map of "West Roxbury Park" was plotted at 100 feet to an inch, as was also that of "Muddy River," both by hired surveyors and draughtsmen under the direction of the city engineer. The party employed on "West Roxbury Park" was in the field over a year and the draughtsmen took months to make the plan so that it must have been very costly. At the same time we find already that the rocks are very inaccurately represented and in many cases not shown at all, and in general the topographical indications can not be implicitly relied upon in the rough, rocky ground, but have to be studied carefully on the ground while planning. The locating of everything that could be measured to with the tape is probably quite accurate, and the leveling also, but a much more valuable map would have been made by a surveyor accustomed to sketching accurately on the ground instead of working up instrumental field notes in the office, and at much less cost.

As to accuracy in general, the boundary and buildings and a few monuments on a place should be located with such accuracy as to permit a plan of roads based on them to be staked out by a different surveyor without any trouble. I should say that errors of measurement of these principal features ought not to exceed one-tenth of 1 per cent on maps at 100-foot scale, but that the minor features, trees, walks, and roads, stone walls, ditches, rocks, etc., might have errors of 1 per cent without causing undue trouble, while the delineation of masses of rock and woods, and the location of contours might be even 2 or 3 feet out. I mean that the main skeleton in most cases should have that degree of accuracy, while the filling in within spaces of a few inches on the map might have the degrees of error mentioned. The rendering of a map for reducing should be much stronger and less detailed than is usual. The Muddy River plan is clear and simple, although reduced, I think, from 100 to 300 feet to an inch, while the tracing for West Roxbury had to be set aside and a new one made because it was too fine in the lines to bear one-half reduction.

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J. C. OLMSTED.

BROOKLINE, MASS., *May 24, 1885.*

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I returned Hodgkins letter as you wished. Did you wish the maps returned also?

He refers to an extreme cost of surveys when he mentions $20 per acre. Of course these are rare cases and represent an amount of detail such as he probably has had no experience of. It includes, for instance, the location of every tree, with notes as to species, spread of branches, and diameter of trunk, also delineation of all rocks and bowlders and accurate measurements of houses and all artificial features, and test pits to show the depth and character of soil, besides very numerous levels and 1-foot contours and drawn on a scale of 20 or 30 feet to an inch. Of course what is done for a given price must be very carefully specified, and even then there is no guaranty practically as to the accuracy of all of the work besides the known honesty of character of the surveyor. We consider a good plane-table survey the best, but for convenience of subsequently staking out work the surveys are usually made by staking out the whole ground into 25, 50, or 100 feet squares, as the case may be, in which case the levels and trees, etc., are determined by measurement from these stakes. If the price is excessive it must mean that too large a profit is charged or that the work is not done by the cheapest method, of course assuming that the quality of the result is first rate. Wages of surveyors I believe run from $2 to $10 per day. When the jobs are small in extent, rarely covering over 500 acres, more often only 20 or 30 to 50 acres, the office rent, profit for general superintend-

Letters from assistants and others, addressed to the chairman of the Conference.

ence, and expenses of all kinds (stakes and fences) must be covered. The fair, ordinary cost for a quality of survey such as suits our purposes is generally about $5 per acre.

The survey is generally made cheapest by the surveyor who lives nearest the ground and who handles the instruments himself.

J. C. OLMSTED.

LETTER FROM ASSISTANT E. F. DICKINS.

In reply to yours of the 25th ultimo, I beg leave to submit the following for your consideration:

For a general coast chart, where the geographical positions of the principal headlands have been determined by astronomical stations and are not yet connected by triangulation, the intervening coast line and topography can be put in rapidly and with sufficient accuracy by a plane-table reconnaissance, such as was made by Assistants Rockwell, Pratt, and myself, along the coasts of Oregon and Washington in 1887. This plan might be used to advantage along the coast of Alaska or any other section where it is not desirable to wait for the triangulation to be executed. But after the coast triangulation is completed I think the topography should be filled in with the utmost accuracy, especially the shore line, outlying rocks, and the positions of all prominent landmarks and landfalls. As to the accuracy of the contouring a great deal will have to be left to the judgment of the officer in charge of the survey.

We are called on constantly on this coast for the use of our topographical sheets in the location of wharves, landings, chutes, mills, etc., and a great many important land cases have been settled by the use of our topographical surveys of San Francisco and vicinity, our maps being accepted by the courts as correct, and the marsh lines, high and low water lines, creeks, fence lines, and other objects shown on our sheets taken in defining and deciding the boundaries of important land claims. The error in the California and Oregon boundary was discovered by a topographical party.

This is a reputation of which we ought to be justly proud, and it should be our endeavor to keep our finished topography up to the standard.

The cost of topography and the rapidity in its execution depend upon the character of the country and the amount of detail to be put in. Were we called upon to cover large areas of interior topography and do more rapid and less accurate work we might adopt other methods, but at present our work is an accurate survey and too many interests depend upon it to allow it to be otherwise.

I do not believe any of us would care to exchange our reputation for quality for that of quantity, and I think it would be a mistake to permit any departure in our work that would lessen its practical usefulness and value.

LETTER FROM ASSISTANT W. I. VINAL.

In answer to your letter of the 25th inst., I submit the following:

With reference to the first suggestion of the Superintendent, I would say (1) that a good review of the present state of the science and art of topography, with illustrations of the various forms of the plane table, may be found, as you are probably aware, in a pamphlet entitled "The economic use of the Plane table in Topographical Surveying," by Josiah Pierce, jr., of the U. S. Geological Survey.

This paper was read and discussed before the Institution of Civil Engineers of London, England, and was published under its auspices in 1888.

In addition to the purely governmental work, on which it is usually employed, the plane table has been used by the harbor commissioners about Boston, Mass., and in making the detailed surveys of the city of Portland, Me., Fairmount Park, Philadelphia, and elsewhere.

2. The classification of topographical surveys must, in my opinion, necessarily be more or less indefinite. For general purposes the country could be partitioned with reference to its geological structure, but the designation of classes of particular surveys to grades would be largely governed by the peculiar features to be mapped. A convenient method of expressing the character of any piece of work, and therefore its grade, would be to name the scale on which it is required to be surveyed, as 1–10000, etc.

3. The practice of the Coast and Geodetic Survey in the use of contours and symbols for the representation of characteristic features would seem to leave but little to be desired.

4. I believe work could be done more rapidly and with a saving of expense in many cases:

(*a*) By using some other material than backed drawing paper in the field work.

(*b*) By having only the most important features represented on the field sheets by the usual plane-table methods and filling in the survey from records made with a transit and stadia. A small transit fitted with stadia lines and vertical arc can be used with great facility in surveying roads through extensive tracts of wood where great precision of representation and contour are not essential. The use of Porro's telescope, described in Johnson's "Theory and Practice of Surveying," would insure the general accuracy of this class of work.

(*c*) By photography in limited areas when controlled by a number of well located points. Photographs would often be useful, aside from affording material for filling in the map, for they would show the nature of the surface, whether regular or broken, smooth or eroded, and assist in the final representation.

(*d*) In surveys of minor detail the prismatic compass and pedometer may often be found useful. Church's American Pedometer has given good results on comparatively level ground.

Letters from assistants and others addressed to the chairman of the Conference.

(*e*) The plane table, as now used by this Survey, might be modified so as to admit of adjustment for eccentricity without impairing its stability. The weight of the instrument can also be considerably reduced by using aluminum bronze in constructing the movements. This metal is largely used in the manufacture of instruments and is in many ways preferable to brass.

LETTER FROM SUBASSISTANT FREMONT MORSE.

In response to your communication of January 25, I have but one or two suggestions to offer, and these briefly, since the time limit set for these replies in Washington has already nearly expired.

In regard to the use of contours, it seems to me that the method adopted on some of the recent published sheets of strengthening certain curves (say every 100, when 20-foot contours are shown) should be made general. In rough and precipitous regions it is well-nigh impossible to trace curves on a sheet unless this be done, and I am satisfied that the practice, once adopted on the field sheets, would prevent to a great extent the error of "dropped" curves.

One other point I would advocate in connection with the fourth paragraph of the Superintendent's opening address, and that is the use of the micrometer eyepiece on the alidade in connection with a somewhat longer rod than that now in use, particularly for rapid reconnaissance work. I have had some experience in this class of work, having done all the plane-table work on the reconnaissance of the coast of Washington from Gray's Harbor to Cape Flattery. In this work I used a small table about (as I remember it) 18 by 24 inches, with an alidade correspondingly smaller than an ordinary Coast and Geodetic Survey alidade. It was fitted with a micrometer eyepiece. The rod used was about 10 feet long, with two fixed targets near the ends. At a convenient place, where there was a long stretch of sand beach, a series of observations were made to determine the number of turns of the micrometer corresponding to distances of 100, 200, 300, etc., metres up to 800, and a table was interpolated for intermediate distances. Thus equipped, the micrometer was used to measure the distance along the entire stretch of coast from Point Grenville to Cape Flattery, and I have no hesitation in saying that the work was fully as accurate as it would have been had the distances been measured in shorter lengths with the ordinary rods, and that in point of speed there was no comparison between the two methods. The average length of sight was about 700 metres between stations, and in two or three instances, where shorter sights were not practicable from the rough nature of the shore line, distances of 1 200 and in one case about 1 500 metres were measured.

It will thus be seen what a decided advantage the micrometer alidade has over the ordinary style for this class of work, and I have no doubt that a thorough trial of it in rough and mountainous country, that is not too heavily timbered, will satisfy any topographer of its utility. In smooth and settled country, where there is much detail, it may not be of much use, as in that case the observer must be near the object he is delineating in order to do it intelligently.

LETTER FROM MR. CHARLES JUNKEN, DRAUGHTSMAN.

In answer to the circular letter from the Topographical Conference, I have the honor to submit the following:

I shall not attempt to treat of the first three themes suggested in your letter, but shall confine myself to a brief review of what I consider the best means of securing data for delineating topographical features. As a basis for an extensive topographical survey, I am convinced of the necessity of an accurate system of triangulation as carried on by the Coast and Geodetic Survey as being in the end the most economical.

In which view I am well supported by previous methods and results. I also highly approve of the plan of running lines of levels from well-defined points on the seacoast, extending across the continent, bench-marks being located at convenient points. I am fully aware that the methods above recommended are apparently expensive, but am convinced of their economy in the end, for it is work that has to be repeated that really proves expensive.

For locating the topographic features I most heartily recommend the plane table, as at present used in the Coast and Geodetic Survey. The tachymeter attachment will prove to be of advantage in mountainous districts, where the stadia may also be used. Elevations on prominent points, as usually taken, will prove sufficient for tracing contours.

I do not consider the results obtained by such methods as captive balloons, rough reconnaissance, photographic surveys, and the like, as at all commensurate with the time, trouble, and expense involved.

LETTER FROM MR. A. LINDENKOHL, DRAUGHTSMAN.

In reply to your letter of January 25, inviting me to send to your board any comments I may desire to express, I beg leave to direct your attention to the second part of a report to the Superintendent upon European methods of surveying and map reproduction compared with those practiced by the Coast Survey.

This report is based upon observations which I made at Berlin and at Paris in 1889, during the Exposition, in obedience to instructions of the Superintendent, dated June 17, 1889.

Letters from assistants and others addressed to the chairman of the Conference.

I also send a pamphlet containing a description of a tachymeter (to be returned); can send you one of the Breithaupt plane table, and hold myself in readiness to answer any specific questions you may be pleased to address to me.

U. S. COAST AND GEODETIC SURVEY OFFICE,
Washington, D. C., October 7, 1889.

SIR: In obedience to the instructions of the Superintendent, dated June 17, 1889, I have the honor to submit herewith, in two parts, my official report in reference to cartography, as exhibited at the Paris Exposition of 1889.

By these instructions I was directed to make a thorough examination of the cartographic exhibit, for a twofold purpose. First, I was to render a descriptive report upon the contributions of the several exhibitors, giving statements of the quality as well as quantity of their work; this is treated of in Part I of this report. Secondly, I was directed to examine into the different methods used by the exhibitors for the production and reproduction of maps, and to submit a critical report upon their relative merits in regard to style of execution and the saving of time and expense; this is treated of in Part II of this report.

The time allowed for the preparation of this report precludes any attempt at exhaustiveness, and only such matters have received special attention as were supposed to be of interest to the Coast and Geodetic Survey.

I arrived in Paris July 28, and called on Gen. William B. Franklin, U. S. Commissioner-General, and on Col. Victor Bernard Derrécagaix, Director, etc., presenting such letters, etc., as had been provided me. These gentlemen afforded me every facility, and I beg to express to them, through you, my appreciation of their courtesy and kindness in facilitating the work intrusted to me. I left Paris August 5 and reported for duty at the Office September 2, 1889.

Yours, respectfully,

A. LINDENKOHL.

Prof. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey,
Washington, D. C.

PART I.—CARTOGRAPHIC EXHIBIT AT THE PARIS UNIVERSAL EXPOSITION IN 1889.

Cartography and geography are not as completely represented at the Paris Exposition in 1889 as they were at the Centennial Exhibition in Philadelphia in 1876 or at the Geographical Congress in Venice in

1881. The absence of Government exhibits by the greater number of European monarchies at the Paris Exposition has been generally ascribed to political motives, but it may also, in part, be due to economical motives, since these expositions occur at such short intervals and entail so great an expense that many States with slender budgets may not be able to incur it. Under these circumstances it is fortunate for those who went to the Exposition for the purpose of seeing excellent workmanship in cartography rather than to inform themselves upon the actual present state of several European state surveys, for the two European countries, France and Switzerland, that have always been in the lead in what is now considered an absolute necessity, viz, the surveying and mapping of the public domain, make so fine and exhaustive a display there of their public surveys. It is, however, only on rainy days or in the forenoons that these maps can be examined with anything like comfort; in the afternoons of every fine day these rooms are packed by a crowd of people more intensely French in feature and expression than I have ever seen on any previous occasion, not excepting one sunny afternoon at the national gallery at Versailles during the proudest days of the Empire. I should have been inclined to attribute this concourse to a strong development of the taste for fine maps in the French people had this not been contradicted by the circumstances that at the very same time the halls of the exhibit of geography and cosmography, which also contained a fine collection of maps, belonged to the most deserted spots of the entire exhibition. It is undoubtedly patriotic fervor or military spirit which prompts the French to frequent the rooms of the War Department exhibit, and even granted that the more showy display of models of soldiers in all possible uniforms on the same floor with the maps offers the greater attraction, yet there was abundant evidence that the people looked with pride at the achievements of the geographical branch of the military service. A very complete catalogue published by the latter and furnished free of charge, contains a great deal of interesting information about the maps as well as surveying instruments exhibited by the War Department.

Taking up the consideration of the exhibit of charts, etc., by countries, we naturally take first—

France.—The most interesting exhibit of maps, etc., at the whole Exposition is that of the French War Department. The walls of two large rooms are set apart for the display of maps, one room for the modern maps, the other for those of older date. Among the maps of older date a section of a map of *France by Cassini* is the first to attract our attention. It is on a scale of 1-86400, and was the first map in Europe which was based upon geodetic operations. Commenced in 1733, it was not finished until 1815. The topography is represented by long hachures, reaching from the crest of the hills to the base, but without any special attempt at minuteness or reference to steepness of

slope. This map appears again reduced to about one-fourth (1–345600), and is called "Capitaine's map of France (called after its author, Louis Capitaine, who was Cassini's associate and assistant); but here the mountains are represented in oblique light. Noticeable also in this room are the maps of foreign countries made by the French engineer-geographers under Napoleon. Thus we find maps of Italie, Suabia, Bavaria, the country bordering on the Rhine, Egypt, etc., all engraved on copper. The method generally adopted by these "engineer-geographers" for the representation of hills consisted in short hachures along the lines of shortest descent with oblique illumination. The last and finest specimens of these works is the topographical map of Corsica, scale 1–100000, published in 1824. Its realistic effect is truly surprising.

In a room containing the modern maps, two selections of the famous map of France at once engaged our attention; these sections represent the regions of the Alps and of the Pyrenees. This map is engraved on copper on the scale of 1–80000 in 273 sheets. It was undertaken for the purpose of superseding Cassini's, which had been found insufficient. Surveys were commenced in 1818 and continued until 1866. The first sheet was published in 1833 and the last in 1882. This map is universally conceded to be one of the greatest triumphs of cartography; although composed of 273 parts, showing the result of the labor of about 800 men, and engraved by over 65 different artists, it has the appearance of having been done by the same hand. The topography is engraved in such an exact and characteristic manner that the true relief of each section is conveyed almost instantaneously. The same map is reduced to one-fourth (scale 1–320000) in 33 sheets, published between 1852 and 1883, and is now being reduced to scale 1–600000, with parts of adjacent countries (in 6 sheets). All these maps are engraved on copper, the relief represented by vertical hachures corresponding to the inclination of the slope.

The publication of the above three series of maps had not even been finished, when experience taught that they would not answer for all the purposes for which they were intended. For many military, engineering, and internal improvement purposes, the scale 1–80000 was found to be too small. Contour lines were desired as being more useful than hachures, and in consequence of the employment of but one color—black—for hachures and outlines of various kinds, such as roads, rivers, etc., these latter were often so much obscured that they could only be discerned with difficulty by a practiced eye. To overcome these defects, the geographical service of the army has gone to work, without loss of time, to supplement, or supplant, the above maps by others on larger scales, on which different colors are employed and on which hachuring is replaced by contour lines and crayon shading. The new

map of France is on the scale 1–50000 (reduced from the surveys on the scale of 1–40000) in 950 sheets; is engraved on zinc in 6 colors—water *blue*, roads *red*, woods *green*, contour lines *brown*, lettering and inferior roads *black*, tinting *gray*. Contour lines are 10 metres apart. In the same way that the 1–50000 is to supersede the 1–80000 map, another new one on the scale of 1–200000 is to replace the one on scale 1–320000; it will be in 82 sheets, also engraved on zinc for 6 colors, and have 20 metre curves. The illumination for the crayon shading is to be vertical in both series of maps except in the mountainous districts on the smaller scale, where oblique light has been adopted for the steeper slopes in order to save the outlines from being obscured (I suppose on account of better effect too). Finally, a map on the scale of 1–500000, in lieu of the one on 1–600000, in 15 sheets (14 already published). This map, like its predecessor, takes in part of adjacent countries; is lithographed in 5 colors—water *blue*, hachures *brown*, woods *green*, contour lines (100 metres apart) *red*, towns and roads *black*. The relief is engraved in hachures with zenithal light for level and oblique light for mountainous regions.

The War Department has also on exhibition three specimens of the map of Algiers, engraved on zinc in 7 colors, to comprise 327 sheets in all; a map of Mexico, scale 1–3000000, and maps of Tonquin on scale of 1–100000 in 13 sheets and 1–500000 in 3 sheets.

Independent of the maps of France published by the War Department, there is published by the Ministry of the Interior a map of France on the scale of 1–100000, in 590 sheets, in colors—*blue* for water and altitudes, *green* for woods, *red* for principal roads, *gray* tint for the relief (oblique light), *black* for lettering, etc. This map is based upon the map on scale 1–80000, but brought up to date as far as concerns public roads, etc. There is also a map of France by the Ministry of Public Works on the scale 1–200000, in 141 sheets, engraved on copper in three colors (black, blue, and brown). The above review by no means exhausts the list of maps of France published at the expense of the Government; and when it is considered that all these maps are based upon the *état major* survey, which is on the extremely small scale of 1–40000, it must be admitted that Capt. George M. Wheeler, in his report upon the Geographical Congress at Venice, does not exaggerate when he says: "On the whole, it would appear that the Government of France has more map-makers than material for maps."

The French hydrographic service exhibits in two places, in the building of the War Department and in the pavilions devoted to geography and cosmography. The surveys made before 1819 are combined in a portfolio; those of later date are hung up on the wall. Among the latter are those of the coast of Tunis, of Cochin China, the Gulf of Tonquin, the Straits of Magellan, and of French harbors. We had just commenced taking down the titles of these charts (although they can all be found in our office and in the Hydrographic Office of the

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Navy) when we were stopped by a soldier on duty, with the remark, "Monsieur, il n'est pas permis de prendre des notes ici." If the guard had been a civilian we might have informed him that we had all these charts at Washington by regular exchange with the French Government.

One ot the greatest sights of the Exposition, only excelled by the Eiffel tower, is the immense terrestrial globe by Messrs. T. H. Villard and Ch. Cotard. It is on the scale of 1–1000000; the diameter measures 12·732 metres and the circumference 40 metres. A conception of its size may be formed by a comparison with some well-known published charts. Thus, it takes two huge sailing charts on even a smaller scale (1–1200000) to delineate the Atlantic coast of the United States from Maine to Florida. The largest and best general atlases do not reach this large scale, even for the most minutely drafted countries. Thus it takes four sheets on scale of 1–1500000 in Stieler's Atlas to show the whole of France, and the same number ot sheets on the same scale for Germany. The globe, however, is not intended to be subjected to very close inspection, and although its general accuracy is to be highly commended, the outlines of the continents and their features are greatly generalized. The mountain chains and the bed of the ocean are not shown in relief, but by colors, because the highest mountains, taking them at 8 000 metres, would appear at an elevation of but 8 millimetres, a dimension which would be scarcely appreciable. It can not be asserted that the construction of this globe solves any geographic problem or advances geographical science, but it certainly is an interesting object to all who take interest in geography, regardless of proficiency.

In the pavilion set apart for "geography and cosmography" there is a large collection of geographical maps, atlases, relief charts and globes, all by French authors, and made at Paris. Among the maps and charts there are many that have no special merit. It is too often plainly visible that the authors themselves were not intimately acquainted with their subject, and the style of execution, as a rule, is inferior to the better class of corresponding German works. Under these circumstances it was an agreeable surprise to find in the examples of the Universal Atlas, by Vivien de Saint-Martin and F. Schrader, published by Hachette & Co., a quality of work that rivals the best productions of England and Germany—the Imperial Atlas, by Keith Johnstone, and Stieler's Atlas, for instance. Their accuracy is unimpeachable, the selection of names shows excellent judgment, and I was especially struck by the beauty of the hachuring, which is very clear, and at the same time sufficiently mellow to leave to outlines and lettering due prominence.

In the matter of relief charts the French certainly evince a great

deal of enterprise and skill, and greatly surpass the Germans. Too much space would be required to mention all the fine models exhibited, but a few may be noticed of special scientific interest. The Alpine Club had a model of Mont Blanc, by Bardin, and one of Mount Perdu (Pyrenees), by F. Schrader; but the pearl of all was a relief chart of France, extending from Paris and Lyons to the Mediterranean, by M'elle C. Kleinhaus. This, I believe, is the relief constructed under Levasseur's direction, and which attracted so much attention at Paris in 1875 and at Venice in 1881.

Switzerland.—Next to France, Switzerland makes the greatest display of maps. There is the celebrated Dufour atlas (1842–'64), scale 1–100000, in 25 sheets, engraved on copper. It is shown in atlas form and twice as a wall map; one a geological map and the other retouched with the brush to heighten effects. The latter especially rivets our attention by its surprising plastic effects. The Dufour map has, since its appearance, been considered one of the greatest masterpieces of cartographic art; its peculiar feature is the selection of oblique light for the steep slopes, as on the backbone of the Alps, and vertical light for the rest of the map, and it is generally admitted that no other method could have been equally effective in bringing out the relief of the *terrain*. There is also shown a reduction of this map to 1–250000, in 4 sheets. It would appear that Switzerland had very much the same experience with these maps on 1–100000 that France had with her 1–80000 map, to wit, that it would not suffice for all practical purposes on account of its small scale and the absence of contour lines. The last sheet of this atlas had scarcely reached the public when the Confederation set about publishing the plane-table sheets on their full scale, which is 1–25000, with contour lines 10 metres apart for the more level regions, and 1–50000, with 30-metre-contour lines for the mountainous regions; the former to be engraved on copper and the latter to be lithographed, and the whole series to comprise 561 sheets, of which about 400 have been published to date. Inasmuch as this atlas is constructed on a different method from the French atlas on the same scale and is rated in Europe as one of the best models for topographical representation, it may be well to indicate the manner in which the three colors in which it is printed have been applied.

Black is used for lettering, buildings, roads, forests, for contour lines where the ground is bare of soil and vegetation, and also to hachure steep slopes and steep rocks in oblique illumination; *brown* is used for contour lines and hachures of inferior slopes in vertical light; *blue* for water and contour lines on glaciers. However effective this method has proved in the hands of the Swiss for the representation of the Alps, the delineation of flat countries, like Denmark, by contours only, without shading or hachures, has been found to destroy all natural effect. No method of representing the relief by contour lines has yet been devised which meets universal approval. The Swiss also exhibit sev-

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eral fine models, and in their attention to this particular method of geographical and topographical representation seem to be, with the French, ahead of all other nations. S. Simon and X. Kufeld have reliefs of the Four Cantons, Mount Rose, and the Jungfrau.

The only other European countries which have official maps on exhibition are Servia, with sections of a map of the state on scale 1–75000 (that of the Austrian atlas), by its major-general, photolithographed in colors, contours *sepia*, woods *green*, principal roads *red;* tolerably good. Russia only shows a model of the Caucasus. The Republic of San Marino has a good MS. map, scale 1–10000, with contour lines 10 metres apart. The Grand Duchy of Luxemburg contributes a good topographical map on scale of 1–40000, which also is made the base of several special exhibits, such as geology, forestry, telephone service, railroads, and archæology.

The excellent lithographed maps of Holland (scale 1–50000 and 1–25000) were not exhibited, but there were several river and harbor charts in the Dutch section, showing proposed improvements.

Whatever may have been the motive of European governments in withholding their national surveys from the Paris Exhibition, this policy does not seem to have been applied to the surveys of their colonies.

Holland has a fine atlas of her East India possessions in 14 sheets, with special maps of Java and Sumatra. As far as regards England, though neither the Ordnance Survey nor the Admiralty Charts were to be seen, there were very numerous, partly official, maps and charts of the different colonies, especially of New Zealand and Australia.

Mexico makes but a small exhibition of maps, though she has undoubtedly taken great pride in her proper representation in other respects. There is but one section exhibited of the "Carta de la República Mexicano," by the "Comision Geográfico," under the Secretary of War (contour lines with oblique shading), and I could not ascertain if there were any more in existence. The general map of Mexico (scale 1–2000000), although bearing the date 1887, did not expecially recommend itself. I have seen much better maps of Mexico elsewhere.

The *Hawaiian Islands* have a general map, "based on government surveys," by S. G. Bishop, 1886, and special maps of several islands by W. D. Alexander, Surveyor-general of the Hawaiian Government survey.

Japan makes a very creditable show. There are exhibited, besides numerous geological and meteorological charts, the following maps as the result of her geological survey, commenced in 1880: Two reconnaissance maps, scale 1–400000, and 12 topographical sectional maps with horizontal contour lines, engraved in Tokio. It is to be noticed that Japan is following an American custom. Like our U. S. Geological Survey and

many of the State geological surveys, it is publishing principally and primarily topographical and geographical maps for the well-known reason that geological surveys without good topographical and geographical surveys and maps as a basis can not be of permanent value.

The above list is believed to complete the review of countries which exhibited the results of regularly organized government surveys. On the part of *Brazil* and many of the *Central* and *South American Republics* there does not appear to be a desire manifested to shroud their geography, but rather the contrary, a desire to bring it into the most favorable light, and several of these countries have engaged the services of eminent French artists (engineer geographers, as they call themselves), members of the Geographical Institute of Paris, to paint the walls of their palaces with maps of their respective countries, showing at a glance its geographical position, its shape, and general features. *Brazil*, *Chile* (also with 3 historical maps), *Venezuela*, *Bolivia*, *Nicaragua*, and *Honduras* are shown in this way. The *Argentine Republic* has adopted a method of introducing herself to public notice which is more novel than and quite as effective as that adopted by her sister Republics, by exhibiting a huge model made as a spherical segment on a scale of 1–500000 (vertical scale 1–100000), based upon the geological examination of Drs. Burmeister, Brackebush, and other explorers.

The *United States*, in their cartographical exhibit, occupy a position of neutrality between monarchical Europe and republican America. They have sent their maps to Paris, but do not appear to be over anxious to attract attention. After having repeatedly looked all over the space allotted to the United States, and inquiring from attendant to attendant I did not succeed in finding a single Coast Survey chart, nor a map of the Geological Survey or U. S. Engineer map, until I engaged the attention of one of the assistant commissioners, who showed me a case in a hidden recess, which he assured me was filled with such maps, but which in no possible way could have been spread out for the want of space.

Models of proposed canals may not strictly have been included in the line of inquiry, but since they furnish such an attractive feature to the Exposition it may be as well to state that the beautiful Menocal model of the projected Nicaragua Canal, which was on exhibition here in Washington about the time it left the artist's hands, was in successful operation, as also were two models of the Suez Canal, one for daylight and the other showing it illuminated by light-houses for navigation in the night. The official guide books had also provided for a model of the Panama Canal, but it could nowhere be found.

All the South American Republics were represented at the Paris Exposition, and those which had neither models nor maps frescoed on the walls had at least a general map suspended, but not always of the best types.

Uruguay had two maps; one by Don F. A. Berra, 1882, and another by Angel Carlos Maggiolo.

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Salvador, a map "political, escolar, and telegraphic," by G. J. Dawson, engraved in Paris, 1887.

The *Republic of Colombia* had official maps of the whole state and of the separate provinces, by Manual Ponce de Leon, 1864.

Paraguay had a map without giving the author or date.

Lastly, *Transvaal* (South African Republic) had a map by Fred. Jeppe, 1889.

PART II.—ON THE DIFFERENT METHODS USED IN THE PUBLICATION OR REPRODUCTION OF MAPS AND CHARTS.

Before entering upon the subject of different methods used in cartography, it seems proper to notice as germane to the matter some differences between the methods and customs followed in making topographic surveys by the U. S. Coast and Geodetic Survey on the one hand and European governments on the other.

Linear measure.—In making surveys, it is the custom in the Coast Survey to make use of the French metre for horizontal distances and of the foot for vertical distances. The necessity of a constant resort to two standards which are not commensurable is not a mere inconvenience, but an actual impediment, detracting from the accuracy and rapidity of the work. It would nowhere else be tolerated. Since it is not to be expected, however, that, after having used the metre since 1817 for all our geodetic work, we shall now go back to the yard at a time when all European governments, with the sole exception of England, have either introduced the metre or are perfecting measures to that end, it is to be hoped that at some not very distant day the metre will not only be used for horizontal measurement, but also for that of the height of the land and the depth of the sea. Such is now generally the practice in Europe; in the flat countries contour lines are given at intervals of 5 and 10 metres, and in the mountainous countries, like Switzerland and Norway, at intervals of 10 and 30 metres.

Plane of reference.—In the Coast Survey it is the custom to take the high-water line as the datum level, and to determine height by the plane table by vertical angles. In Europe all heights are referred to the mean level of the sea, and no plane-table survey is undertaken unless a sufficient number of bench marks has been determined by a system of precise leveling. It would probably be considered injudicious to make a change in our rules at this time when our survey is nearly completed, but our experience in executing work for special engineering purposes is such as to warrant the belief that in the future, in all work of a critical nature where a fraction of a foot is a consideration, and for all work which shall rigorously comply with the highest scientific requirements, the effects of the tide will have to be eliminated

from the levels, and the sensitive spirit level be substituted for the alidade.

Scale of plane-table sheets.—The experience of the Coast Survey through a long series of years teaches us that the adopted scales for topographic surveys, viz: 1–10000 for densely populated districts or intricate work, and one 1–20000 for sparsely inhabited and less valuable sections of country, are the very best which can be devised. In the face of this experience it is rather surprising to find the majority of European countries using the very small and rather odd scale of 1–25000 for their plane-table surveys. The explanation is to be found in two circumstances, the first of which relates to the scale of publication generally either 1–50000 or 1–100000. The scale of 1–25000 is preferred to that of 1–20000 because much stress is laid upon a simple ratio, one-half or one-fourth being considered more intelligible than one-fifth or two-fifths. The other reason for the retention of the scale is to be found in the diminutive size of the European plane-table sheet; it averages about 17 by 20 inches, while in the Coast Survey sheets 30 by 52 are worked on with the greatest facility. The desire to keep the number of plane-table sheets within reasonable limits may also prompt the adoption of this otherwise inconvenient scale. It takes 5 206 plane-table sheets for the survey of the German Empire alone. If the scale were to be increased from 1–25000 to 1–20000 the number of sheets would be swelled to over 8 000.

Scale of publication.—The European governments do not appear to have arrived at any agreement for uniformity in the scale of publication of their topographical surveys. England adheres to 1–63360 for her general maps; France has adopted 1–50000 for her new map in place of 1–80000; Germany and Switzerland prefer 1–80000, and Austria 1–75000. For the coast of the United States the scale of 1–80000 was selected very probably for the reason that at the time the selection was made the map of France was the only national publication in Europe of sufficient merit to be taken as a model. However, our experience with this scale has not been unlike that of France, as it has been found too small for the preservation of all the detail of the survey and for many practical purposes. Thus the whole of the coast of Maine had to be reproduced on the scale of 1–40000, and there are harbor charts published on a great variety of scales from 1–5000 to 1–60000. While the diversity of scales can not well be avoided, it would be well to follow European custom by abolishing such scales as 1–50000 and 1–60000, and to confine ourselves to the use of simple ratios, say, 1–40000, 1–20000, 1–10000, etc.

METHODS OF PRODUCTION AND REPRODUCTION OF MAPS.

In taking up the subject of methods of map production in connection with the Paris Exposition, it may be just as well to set at rest the question that has been put and answered a hundred times, but is sure

to come up again. The essence of this question may be stated in these words, "What is the use of going to an exposition to look at maps that you can see at home in your library?" When you look at a map in a library it occupies the position of a client, and you can not entirely free yourself from the prejudice, but when you look at the same map in an exhibition you divest yourself of your individual opinion, you act as an umpire and reflect the general opinion. A good map never appears to better advantage than when on exhibition, and a poor map never looks worse than when in contrast with better ones. It may also be stated at once that some of the modern processes of map-making did not have their proper exponents at the Exposition, and therefore much information had to be sought for elsewhere.

Copper engraving.—With all the great advances that have been made within the last few decades in the method of producing maps, the fact stands out patent that nothing has yet been devised that will equal a good copper-plate engraving. For this reason the most respectable establishments go on, as heretofore, and have their best maps engraved on copper, and although a great deal is said about the scarcity of engravers, I have not learned that either the British Admiralty or the U. S. Coast and Geodetic Survey, both of which carry on very extensive operations of this kind, have been seriously embarrassed on this score. The cost of the material need not be taken into consideration at this time, when copper is so cheap as to be substituted to a large extent for iron and tin for common building purposes. The advantages of copper engraving, besides the superior elegance, are its durability and the facility with which corrections and duplicates may be made, and its only serious disadvantage is the greater expense of printing.

Heliogravure.—When the Austrian Government, in 1875, emerged from the field of experiment and commenced the publication of its atlas of 720 sheets by heliogravure instead of by hand engraving, an undertaking which I believe has since been carried to a successful conclusion, not a few people were of the opinion that, on account of its great saving in time and money, it would in a great measure supersede the old-fashioned style of hand engraving. The late Dr. A. Petermann, as appears by a contribution to his Geogr. Mittheilungen, written shortly before his death,* seems especially to have taken quite an enthusiastic view of the future of heliography, but we find after a lapse of over ten years that it has not made much headway. The Prussian Government, after making some experiments, wisely determined to go on with hand engraving, and even at Gotha I could not learn that any of the engravers had been pensioned and draughtsmen substituted for them,

*See Petermann's Geogr. Mittheilungen, 1878, pp. 205 to 210.

and Steiler's Atlas is still engraved on copper, as heretofore. The fact appears to be that the Austrian Government took to heliogravure more from necessity than from choice; it had allowed copper engraving to fall into decadence, instead of nursing it, and in its stead raised an excellent corps of topographical draughtsmen. Dr. Petermann estimated the relative expense of engraving and heliogravure as 4 to 1, and I do not think that he exaggerated the difference, but what could be done in Austria may not be done as well elsewhere. Where will you get the requisite number of draughtsmen who can draw as sharply as an engraving and will not require at least as good pay as an engraver? And what if they spoil the job, not to mention all the uncertainties of chemical and optical action? The great defects of heliogravure are common to all patent processes intended as substitutes for engraving. Drawing never is equal to an engraving, and the heliogravure of a drawing never excels and rarely equals the original. The great trouble is with the faint lines, which will not come up as well as the heavy ones, and for this reason, even in Austria, all outlines, water lines, and straight lines are cut in by hand.

Zinc engraving.—About the only advantage zinc has over copper for engraving purposes is its greater cheapness. In every other respect it is inferior. Its texture is crystalline, it is brittle, and for this reason it will never be a favorite with the engraver, who calls it a rotten metal, and will charge more for work on it than on copper. At the French War Department the new map of France, on scale of 1–50000, is engraved on zinc for six colors on 950 sheets, which alone requires 5 700 plates. In order to insure the proper registering of the six plates for each sheet, all the outlines, except the contour lines, whether intended to be *black*, *blue*, *green*, or *red*, are engraven on one zinc plate and transferred to the respective color plates by dry prints. The engraving appears to be quite well done, but this is no reason why zinc engraving should be recommended to other establishments. The French have their engravers trained to the metal; the work is exceedingly plain, and its only advantage is the greater cheapness of zinc compared with copper, while it has the disadvantage that it can not be manipulated as well by the engraver, and that corrections can not be made as easily and repeatedly as on copper.

Lithography.—Since the advent of photolithography the lithographing of maps has greatly fallen into disuse, and the only reason that it is still carried on to some extent in Europe, notably in the reproduction of the plane-table sheets of the Swiss and Prussian surveys, is the fact that there are an abundance of good lithographers at hand and a corresponding want of equally good draughtsmen; and, furthermore, the objection that these governments do not wish to change the plans of great national undertakings while under progress of successful execution.

The reason why the lithographing of maps is still persevered in by

some private establishments is the fact that much lithographing is done for commercial purposes, blanks, bill-heads, etc., and the engravers may better devote their spare time to map-engraving than to idleness. The great objection to lithography for map-engraving is its perishable nature and the difficulty of making corrections. Although it is not a subject of emulation, it is a fact that some of the finest atlases, like those of the Netherlands, have been engraved on stone, and it will forever remain a subject of great regret to the enthusiast in cartography that such a fine monument of a model topographical survey as that of the former electorate of Hesse-Cassel should have been engraved on stone instead of on copper. Even if it should be possible to preserve these stones in good condition for an infinite time, they are too cumbersome and expensive to warrant the experiment.

Photolithography.—The introduction of photolithography, about twenty years ago, for the reproduction of maps, has wrought quite a revolution in the practice of cartography. The possibility of having it in one's power to have any map, in fact any drawing, reproduced in any desirable number of prints, or any desired scale, nearly equal to the original, at the shortest notice and at small expense, is the great achievement of photolithography. At the time when nearly all cheap maps were lithographed, the drawings were hardly ever made with the finish which they were expected to receive from the hands of the engraver, and, as a consequence, too much was generally left to the judgment of the engraver, and errors crept in which it was difficult to correct upon the stone. Now, with photolithography the mental work is all done by the draughtsmen, as it should be, and the mechanical part only by the artist. Another great advantage of photolithography lies in the fact that the originals can be kept without expense and be corrected and reprinted whenever required. Some of our progress sketches have in this way been corrected and reprinted for more than ten consecutive years without any injury to the drawings. A stone would not bear such repeated corrections, and would represent a dead capital whenever not in actual use. It must not, however, be supposed that photolithographing maps is an easy matter. In order to obtain the proper scale and dimensions, and to get the photograph properly developed, a fine apparatus, great skill and experience are required; all matters in which different methods and practices, usually regarded as secrets of trade, prevail. There are a number of establishments in this country, that are not surpassed by those abroad, which pay especial attention to the photolithographing of maps, and give the greatest satisfaction to the several branches of the Government from which they find extensive employment.

Transfers on stone and zinc.—Whenever large editions of a map are required and great delicacy is not a consideration, it has been the cus-

tom, in order to save time and expense, to print copper and stone engravings from transfers on stone. The French print their new map of France in six colors and their map of Algiers in seven colors, engraved on zinc and from transfers on zinc. The French appear to be altogether inclined to do too much cheap printing from zinc transfers. While they even place in the market cheap zinc transfer prints of their fine map of France, engraved on copper, the German Government only sells proofs from type plates. When it is taken into consideration that to have the new map of France always ready for the printer would require 5 700 separate stones, which would not only represent a very respectable investment, but would also demand a very large storeroom and prove a most unwieldy mass of material, we can appreciate the good judgment of the French in substituting zinc plates, all of which can be encompassed in a closet of moderate dimensions, always ready and convenient for use. A great deal may be said against the employment of many colors, and the French may be said to have quite reached the limit of artistic propriety and to have gone more than half way to meet popular indolence. The employment of three colors—black, blue, and brown or red—may be considered quite sufficient to facilitate the reading of a map; still, the same objection against the use of stones for printing even with the few colors holds good, and it is rather a matter of surprise that the French have no followers in this practice. As long as our Government has no establishment of its own for printing by transfer, it can only be a matter of indifference whether this printing is done from stone or zinc if it is properly served by private firms. Some private firms do a good deal of cheap printing from zinc plates, especially crayon work, but are disposed to speak disparagingly of the use of zinc for map-printing. There may be some prejudice against the employment of zinc by lithographic printers on financial grounds, by reason of a large capital invested in stones, yet it remains true that transfers on stone are finer and in every way superior to those on zinc for maps and line work, because the zinc, for the manipulation, requires a grain which, however fine, interferes with the sharpness of the lines. The difficulty or impossibility of making correction on transfers on zinc also operates against its employment for maps or chart printing. There may be emergencies, such as happen in times of war, when it is desired to obtain the greatest possible number of prints at the shortest notice and when the compliance with specifications by which time is lost is suspended; those would appear to be the occasions when printing from zinc transfer would be in order.

It may be mentioned in this connection that the U. S. Geological Survey had the subject of zincography, as practiced by the French War Department, brought to its attention, but after carefully investigating the subject in all its bearings, concluded to defer action and go on in the old style of engraving on copper for three colors and printing by contract from transfers to stone.

No special reference is made to the process of photozincography as

Letters from assistants and others addressed to the chairman of the Conference.

practiced by the English Ordnance Office, because it is only applied in the production of parish plans on the very large scale of 1–2500. Nor shall I attempt any description of the several processes of photogravure, zincography, and photolithography, as practiced at Vienna, Paris, and Southampton, because such descriptions by a nonprofessional do not amount to much, and no secret is made of their methods by the several governments and all desirable information is always cheerfully furnished.

After a review of the principal methods of producing and multiplying maps I arrive at the conclusion that about the same condition of things exists therein as in surveying, where there is no such thing known as a universal instrument, or one that would serve all purposes equally well, but where, under certain conditions and for certain purposes, there is always some particular instrument or some instrument of peculiar construction, which deserves preference. In a similar way I find that there is no one method of map production that could be recommended for general adoption, but that each method has its merits and defects.

LETTER FROM MR. F. C. DONN, DRAUGHTSMAN.

Your letter of January 25 has been received with inclosed copy of memorandum of the Superintendent's suggestions, and invitation to send to your Conference, in writing, any comments thereon that may seem appropriate.

Thanking the Conference for the courtesy so extended, I beg leave to say, that having been out of the field since 1878, excepting several short intervals, I have not informed myself concerning improvements in instruments and methods of work.

Principally occupied in hydrographic draughting, but few topographical sheets have been examined or studied. Those which have come under my notice, however, have convinced me that a number of improvements might be made by the topographer in the direction of conventional signs. Of course the topographer who makes the survey and inks his own sheets has no difficulty in the matter, as every feature will be present in his mind, but when it is remembered that few draughtsmen are topographers, I think every detail of the work should be so represented when the sheet is finished that any draughtsman would be able to make a copy with absolute certainty as to the meaning intended.

I will state briefly some of the difficulties experienced.

High-water lines should be continuous, but in some cases they are lost or covered up by other features. These lines should be the most prominent feature of a sheet and their position never doubtful.

The line separating the highland from the marsh is variously represented by a continuous line, a dotted line, or by a continuous line with short hachures at right angles to it, by lone hachures or ends of the parallel lines significant of marsh areas. The continuous line is often mistaken for that of high water, especially when creeks intersect the marsh. This making of marsh boundaries should be represented in such manner as would prevent the possibility of mistaking them for the shore or high-water line.

Salt and fresh water marshes in many cases can not be distinguished apart.

Contours cause a great deal of trouble because too few heights are given. In the case of bluffs or steep slopes when the curves merge into them, it is difficult to fix the heights of the crests. In minus curves or curves of depression the conventional sign is very frequently omitted. The elevation of such D curves should be indicated to prevent the possibility of confusion or uncertainty.

These instances are taken from practical knowledge of the difficulties under which draughtsmen labor; the sheets containing them are of recent surveys.

These points may have already been brought to the notice of the Conference, and if so, one more witness from the draughtsman's side may give emphasis to the matter.

If I may be permitted to make a suggestion, I will say that the office will be more efficiently served if each topographical draughtsman could have a season or two in the field work in sections which afforded him the largest opportunity to study characteristic features, under the direction of some skillful topographer of the Survey.

SUPPLEMENT B.

THE TOPOGRAPHY OF THE COAST AND GEODETIC SURVEY, WITH RELATION TO ITS DEVELOPMENT AND FURTHER POSSIBLE DIFFERENTIATION, WITH A CONTRIBUTION THERETO OF A DESCRIPTION OF A PRACTICABLE METHOD OF BALLOON SURVEYING.

[By Assistant R. M. Bache.]

The topic which I here beg leave to present to my fellow members of this Conference, and crave for it their careful consideration, is that of topography, regarded in its broadest and also in some of its minutest aspects, beginning with its evolution on the Coast Survey. In attempting to present you with this view of inception, progress, and final accomplishment, I bring to bear an experience since my boyhood, which experience necessarily includes that of others as well as my own, digested finally in my mind, all bound up in clear recollection of the phases through which observation of others and personal effort have brought to me firm conviction upon the points upon which I purpose to enlarge.

Inasmuch as the development of accurate and elaborate topography is a product almost confined within the present century, it will not be necessary, in the customary way of exhaustive discussions of a subject, to go back to the flood, when the dove, as assistant topographer, brought in a sketch of the condition of the earth's surface, followed soon by Noah's first survey of the summit of Mount Ararat.

Referring simply to this country, where elaborate topographical methods and performance, partly of native and partly of foreign inception, have reached so high a degree of excellence as at present, not excelled at any time abroad, and that within so limited a period as within the century, I would first of all call attention to the circumstance of evolution everywhere of extended, fine topography being almost confined within that limited period. Naturally it had to wait for geodetic triangulation. Next, it is to be particularly noted that the first piece of extended, accurate, and elaborate topography in this country was that executed by my father, Capt. Hartman Bache, then of the Topographical Engineers, U. S. A., between the years 1821–'25, several years before the Coast Survey was in effective operation. Comparatively crude as it was in graphical presentation, as compared with later similar work, for at that time conventional signs were very unsettled, the map which was the product of that survey, taking in Charleston harbor and city, South Carolina, including hydrography as

well as topography, and extending inland much beyond the future work of the Coast Survey, was accurate to a degree seldom equaled and never excelled for its scale, as in the course of Coast Survey work I subsequently had the means of ascertaining, and as was similarly testified to by Army and Navy officers during the war, when they had occasion repeatedly to refer to the work in connection with military operations near Charleston.

Some twenty-five years after the execution of this work, when, as a mere boy, with scarcely any experience of topography, I was present at a conversation between Capt. (then Major) Bache, and our chairman, Mr. Whiting, then my chief, who, young as he was, was in proficiency even then the Nestor of topography on the Coast Survey, I heard on the one hand the latter speak in the most complimentary terms of the excellence of that Charleston survey, and the former, on the other hand, deplore that at the period concerned he had not had the facility for topographical work that the plane-table affords.

I do not intend to imply by what has been said that this Charleston work was executed single-handed by Capt. Hartman Bache. On the contrary, as I am speaking to the point, first of all, of the evolution of topography in this country, I wish it to be clearly understood that he had as assistants with him several officers; for the operations of the Topographical Engineers then, like those of the Engineers now, and always, were conducted on a generous scale of life for educated men. The junior officers, as assistant topographers, were Lieuts. James D. Graham, C. M. Eakin, and W. M. Boyce, all belonging to the Topographical Engineers. They were well grounded in the principles of accurate work, and Eakin, who with Boyce afterwards went on the Coast Survey, was a born topographer, for the topographer, like the poet, is, as you know, practice in his art aside, born, not made. Eakin coming, through his advent upon the Coast Survey, upon its accepted topographical instrument, the plane-table, did not for the future labor under the disadvantage which Maj. Bache had regretted in his own behalf. He did admirable work with that instrument, and being well instructed in its employment, his pupil, our present chairman, took a much higher flight than he in excellence, producing, with his singular aptitude for the plane-table and topography, maps that, within their individual scales, never can be excelled in effective graphical delineation of ground.

In what I have said there is no disparagement of the foreign topographers who came in with Mr. Hassler as Superintendent of the Survey. They worked according to the general requirements of a period when funds were lacking and large areas had to be hastily covered to make a show of production, upon which the very life of the Survey hung. The standard of accuracy, moreover, even among surveyors and engineers, was then much lower than at present. They worked up to the general requirements of their day; few men ever do more. The particular set of men who did more than that I have mentioned,

and my conviction, from having in the field touched upon the earliest work of both native and foreign topographers in this country, is that the palm of excellence is due to the former for accuracy and elegance in topography, finally permeating the whole of that sphere on the Coast Survey, and that, foremost of the men to whom that result is due, and without whose impress it is questionable if the topography of to-day would stand as high as it does, was our honored chairman, Henry L. Whiting.

It follows, as a legitimate inference from the point upon which I first of all dilated, that I deem the modernized plane-table the best topographical instrument extant. I say more, that it is the best topographical instrument possible, for the simple reason that it combines the office with the field; that whereas the field-transit entails the maximum of elaborate notes, and the maximum of precise sketching, and not only renders it possible and certain that discrepancies will manifest themselves eventually in plotting, even when the greatest care has been taken in the field, and also that, to obtain final results, there must be a great expenditure of time, its final product for elaborate surveys (and we are supposed to be speaking only of those at present) is, as compared with that of the plane table, at best bald and skeleton-like, unless play be given to the imagination, which should have no part in topographical delineation, save in the acceptance and artistic treatment of conventional signs.

It follows, if what I have asserted of the plane-table as compared with other topographical instruments be true, that its performance in given hands is the most crucial test of the expertness of a topographer. Every case in topography is, as you know, a special case, from the determination of the individual station, through the details that shall be obtained from a particular station, through the whole succession of stations which in sum produce a survey; which include in their entirety the best mode, in generals and particulars, of attacking the ground. Back of the choice of a particular instrument for topography lies for good work the determination of the question of the scale to be adopted for a certain map, a question too often neglected. It should, nevertheless, be obvious that the scale to be adopted is properly determinable only upon the basis of the previously settled question as to the exact purpose of the survey. It is as preposterous to adopt a scale too large for the precision and elaboration to be devoted to a map, as it is to adopt one too small for the precision and elaboration desirable. In any event, however, whether the scale be well or ill chosen for a given purpose, the plane table remains paramount as the instrument of instruments for topography on any scale.

But in saying this I do not mean to imply that the plane-table may not employ useful accessories, however skillfully it may be managed. Although it is, in its modernized form, virtually perfect for its purpose,

I can not but think that some useful accessories to it have not been sufficiently employed. In its capacity, through easy angling upon or telemetering to subsidiary objects, to determine them, nothing can be conceived as affording greater facilities for all horizontal work. To some degree, through the arc of its alidade, by means of which we can, for moderate scales and over small regions, obtain elevations with sufficient accuracy, it compasses the determination of heights, and to some degree also it may be used, through its modernized alidade, as a leveling instrument, although that method of leveling, involving the use of the whole heavy instrument, does not in practice lend itself favorably to the execution of extended leveling. I was therefore driven, early in my experience on the Survey, believing, as I did, that our vertical work in topography was unduly below in accuracy the standard of our horizontal work, to employ special leveling instruments of a greater or less degree of precision, as the case might seem to require. About 1853 I exhibited to Prof. A D. Bache a hand level (Locke's) which I had used for a short time, in whose working he took great interest, trying it with me out of a hotel window in Savannah, Ga. Contemptible as the instrument is as one of precision, it yet serves admirably as an accessory to plane-table work in a hilly country, and at any rate, I judge, from the evident ignorance at that time of Prof. Bache about the instrument, that I had the honor, such as it is, of introducing it upon the Survey, where it has proved useful, and indeed sometimes, in careful hands, performs beyond what one might expect of it, as Prof. James D. Dana once proved to me, by showing me the results of a line of levels which he had run with it between points of which I had obtained the elevation by regular spirit-level determination.

The measure which I should like to see adopted for fine vertical work in hilly country, in conjunction with scales not exceeding 1–5000, would be the general introduction of the spirit level for the production of critical points of precision at, say, the moderate limits of half a mile apart, over the whole area, and of the *niveau d'eau*, the French water level, wherever desirable within those limits. Just as our delineation of all horizontal features of a country depends primarily upon the establishment of critical points, supplemented when required by tangents, so the vertical delineation of the same country should be made commensurate in accuracy with its horizontal delineation, by means of the establishment of critical points of reference for elevation. My method of accomplishing this to the best advantage, in a case which required special precision, although the scale was only 1–10000 (for the survey was for minute geological purposes), was by running some approximately parallel lines of spirit leveling through a nearly square area ot about 100 square miles, tying on, where facility offered, intermediately to their termini, and then supplementing with other levels within the areas circumscribed, by means of the *niveau d'eau*,

which I have had constructed with simple gas pipe and elbows, the whole instrument with its tripod not weighing over 5 pounds. With this rapidly-working instrument one can run a mile of levels with a probable error not greater than two or three-tenths of a foot, far within any necessity of scale. Within four years an official of St. Louis, Mo, who was my assistant there during the war, when I made a survey from St. Louis to Carondelet several miles below on the Mississippi, wrote me that the aforesaid work remained to that day the best authority that the city possessed, whereas the work above it, with which mine joined, executed without any system of leveling, was entirely worthless to the city. Yet the *niveau d'eau* was the sole leveling instrument used, carrying elevations accurately over several miles.

There is another instrument, useful as an accessory to plane-table work, which I should not omit to mention because it happens to be of my own invention. This is merely a telemeter, reënforced on its back by a strip of wood, to stiffen it, and supported on a vertical stanchion, from which it is detachable, and on which it can be revolved by the sketcher in the bow of a boat. It is graduated to 5 metres, and can be read intermediately to 1, for a distance of 300 metres, or, of course, by doubling up, to a distance of 600. For all calm waters, with margins upon which it is impracticable to stand, for all shores covered with high reeds, nothing can take its place. When I look back to the time lost in former years in placing tags on withes, and then determining their position, under the difficulties sometimes of special stations for the purpose, the facility with which I have long been able in such places, with the assistance of a good sketcher, to sweep in a large area with perfect accuracy has been quite delightful. In such places the expenditure of time and trouble, as experienced in the general method of obtaining them, is reduced by comparison to nothing.

Speaking of material things as useful accessories to plane-table work should not lead to forgetting that the service of at least one good sketcher, preferably two, is a most useful adjunct to the work of the chief of a topographical party, whose general presence at the instrument, as the focus of operations, is indispensable to the execution of the most rapid, consistently with its being the best work. This class of men has not been sufficiently fostered on the Survey. Represented by individuals who assist like "hands," carrying, pulling an oar, etc., it only needs that their moderate pay be made continuous, and that they be transported from place to place, to secure a class of men as a part of the personnel of the Survey, that would add immensely to the relief of chiefs of topographical parties and prove of advantage in the economical production of work.

I mentally admit in my scheme for improving the art of topography the largest range in actual practice. I begin always, as I have said,

with the question of the purpose of the particular survey in contemplation, upon which depends, as I have also said, the determination of the scale which should be adopted. Upon the scale adopted for it, in turn, should depend the greater or less attempted elaboration of both horizontal and vertical work. A map may legitimately be on a scale so small as to preclude detail to a degree that necessarily makes of it a sketch in character, but one can not legitimately be on a scale so large, with reference to actual elaboration, as to profess, while in fact virtually a sketch, to be accurate and comprehensive up to the capacity of its scale; and yet that is exactly what every large scale map, without corresponding accuracy and fullness, and without qualifying notes, falsely professes to be. In a word, the being in fact that which a map on its face professes to be, is indispensable truthfulness in topography, in every delineation of the earth's surface, from geographical maps down to and through every phase of topographical representation.

In saying, as I do, that the sole condition of the truthfulness of a map is that it shall be that which on its face it pretends to be, is necessarily involved the admission that maps may legitimately have, dependent upon their purpose, and therefore, as should follow, upon their scale, various degrees of accuracy. There is a great gulf between the survey and map for the construction of a fortification on hill and escarpment and the survey and map for any other purpose that can be mentioned as detailed. In the whole range of surveying, however, one kind of survey is no more legitimate than another, all having their appropriate place, if only the scale represents the truth up to which the operator has worked.

So clearly am I of the opinion that the present recognized extensive range of surveys and maps have their legitimate provinces solely upon the condition that they shall be truthful in the pretension which they make on their face, that I am emboldened rather to suggest adding to than subtracting from the present range of map-making methods and map products.

PHOTOGRAPHIC TOPOGRAPHY FROM A BALLOON.

I deprecate any hasty, adverse conclusions on the subject which I am about to present. Experience in life shows the general tendency to resist innovation. The history of invention proves the fact conclusively. Premising then, and insisting, lest my meaning be misconstrued, upon my recognition of the facts of the possibility of failure and the existence of limitations to the applicability in places of the plan which I am about to suggest for particular purposes and places, I state now those limitations to be, so far as they are at present apparent to me, strictly circumscribed by character of country, size of scale which it is possible to use, and appropriateness of the method only to one specific kind of survey. But, as to the last clause, it may well

be urged that if only one purpose in anything be well subserved it is distinctly a gain in the affairs of men.

The idea of photographic topography from a balloon had occurred to me before I learned that it had been thought of by others and experiments tried with a view to its realization in practice. I was not surprised, however, to learn eventually that the idea had been conceived by others, knowing, as I well do, that as never before the world teems with ideas as to applied science. So far, however, as I am able to ascertain the results of these experiments, they do not stand test as results of precision, such as warrant my regarding them as representing methods capable of executing regular, accurate, reliable surveying. But, on the other hand, I venture to believe that my method, hereinafter described, if applied strictly within the conditions which I carefully note, will be found to meet all the requirements which thorough knowledge of the general subject would impose.

Given a tract of moderate accidents of surface, and, although not unwooded, destitute of forest, and I believe one would have the physical conditions fulfilled necessary to carrying out the plan of survey which I have in mind, costing very little money, and yielding immediate results, which could easily be refined upon as a final product of the survey. To take a simple case, imagine that, in a country such as I have described, a map were required to be made on and for some distance on both sides of a traverse line in process of execution. Select two stations of the line that have been occupied by the instrument for horizontal angles and mark them with two disks of white muslin, say stretched on hoops, of a size determinable by the distance at which they are to be viewed by the camera; midway on the line between the stations send up a small spherical balloon, with a camera pointing vertically downward suspended from it, and captive by four light cords, two of which should coincide in position with a vertical stripe passing around the centre of the balloon, and adjust it, in an obvious manner over the traverse line, at a height which determines the scale of the map of the area assumed to be possible of delineation. The proper elevation of the camera for the purpose of photographically including a single link of the traverse line, thus, as remarked, establishing the scale of the map, could be preliminarily established by experiment on the ground merely by setting up the camera in the usual horizontal position, so placed as to distance from a horizontal base representing the length of a maximum traverse link as photographically to reduce it to the desired scale; and as to direction so placed as to be on the perpendicular to the middle of that base.

The balloon should be centered over the point below without instrumentally aided observation, the vertically placed stripe ranging along the link, and the apparatus being anchored by light weights, with rings through which the cords could reeve, to cover the necessity of

making any adjustment of the length of one or more of them, growing out of some accident of the ground. On one of the two traverse stations representing a given link of the line the disk of white would necessarily be larger than that on the other, so as to indicate on the photograph the direction in which the survey proceeded. The camera would also necessarily play in gimbals of sufficiently easy movement, short of permitting it to oscillate with perfect freedom, of just such ease of movement as to permit it to maintain perfect horizontality. In addition to the four light cords mentioned, to be attached as guys to the balloon, for the purpose of orienting and keeping it in position, a free one, graduated downward in feet, and containing the wires in electric communication with the photographic shutter of the camera, actuated by a minute battery, would complete the whole apparatus. With due care in manipulation, the camera, lying with relation to the vertical stripe on the balloon, would be oriented with the stripe along the given link of the traverse line, and register the link essentially in the middle of the plate, and its termini within the margins of the plate.

It stands to reason that these operations would be impracticable in a high wind amounting to a gale. In a calm, however, or in moderate breezes, such as are concomitants of fine weather for field work, there is apparently little ground to doubt that the picture of the earth under the camera could be successfully taken in the manner indicated.

Any one who has flown kites, and therefore knows the stillness of them when properly constructed as to both figure and attachment, and when fully raised, can little doubt that a miniature, perfectly spherical balloon, floating in the atmosphere, held at four points equidistant from each other around the circle, would have no tendency, like an ordinary balloon, to sway, owing to the fact that its center of gravity, unlike that of the ordinary balloon, would be close to the inflated body. It would be like a kite flown from four directions, but much more stable.

How important figure and attachment are in the case of the kite is known to many persons from experience, but as many have not considered what influence those factors combined would effect in the case of a specially constructed captive balloon, it becomes here necessary to demonstrate them, through describing the construction and mode of management of the balloon adapted to the case in hand; how, through figure and attachment, the forces in play may be so combined as to produce equilibrium in the object acted upon.

In the first place, as to figure, the balloon, unlike the ordinary æronautic one, with its long neck and remote car, would be perfectly spherical, with the gimbals and dependent camera set close to its periphery. Thus closely ballasted it would, if free, have no swinging movement, and would therefore have no tendency to swing when held by centralized equiangular forces around its periphery. As for the particular feature of its attachment, which relates to the equalization

of the forces designed to retain it in position, that would be by fastening the guy cords equidistantly on a light girdle passing equatorially around the sphere as resting when ascended. It will be perceived that this place of attachment, combined with the figure and mode of ballasting mentioned, precludes oscillation, even when the lateral force of wind is introduced, unless, indeed, the balloon has not been gifted with sufficient ascensive force. The balloon, thus constructed and attached, should present stability all-sufficient for its object. But additionally to these guarantees of stability is to be added a momentary one at the critical point of time of taking the picture. At that instant the operator would stand directly below the balloon, holding in his hands the little battery and the graduated cord containing the reophores actuating the photographic shutter of the camera. At that instant he would draw the cord tense, and simultaneously complete the electric circuit of the battery, and in a small fraction of a second the picture would be taken.

The preliminary determination of the question of scale will have settled the height of the camera during the whole work, the fixing of the focus for that height, the size of the diaphragm for limiting properly the angular aperture of the objective, so as to obtain a sharp picture, and the maximum distance allowable between stations, which, however, should, for convenience sake, be as nearly equidistant as possible.

Cameras, except some of the English ones, are now made so extremely light, not over five or six pounds in weight, that the size of the balloon necessary for the purpose described would be correspondingly small. So small a superficies, moreover, as it would contain could be prepared without great pains, so that the balloon would almost indefinitely retain its gas. This gas would necessarily have to be on occasions generated by the surveyor for his own special purpose, and on such occasions would necessarily be hydrogen, heated air being inadmissible for the purpose discussed. In many cases, however, coal gas would be easy to procure, and could then be employed. The War Department balloon service now employs gas under high pressure, in steel tubes, easy of transportation. The use of such, therefore, would afford the greatest facility possible in the operation herein described.

We are now supposed to have secured, as the result of running a traverse line, in the manner described, a number of negative dry plates, impressed by instantaneous photography. These can be stored away in the dark compartments used for that purpose until such time as may be convenient to develop them. They are often thus kept perfectly safe for many months. Being finally developed they are cut off with a diamond point at such angles as will enable them to fit on the traverse line plotted on paper previously to its being sensitized.

The traverse line, as penciled to scale on paper, subsequently sensitized, would necessarily fix the directions of the photographic representations of its individual links, and the photographic representation to scale of the links on the ground would give the means for adjusting the plates on the paper; an operation, it will be perceived, thus checked by the distances to scale as actually measured between the stations of the ground; a perfect accommodation between the data, as obtained above and below, being thus effected by a slight adjustment. In order to limit to the minimum in space, the narrow wedge-shaped blanks that must occur between plates lying at an angle with each other, corresponding with their relation to nature, along the representation on paper of a traverse line thus treated, the line on the ground should be run as little zigzag as possible.

By means of lines tying on at intervals one traverse line to another, the same scheme of work could be amplified laterally. If that were done, however, one picture would overlap another, the wedge-shaped blanks would be multiplied, and the resultant print would be irregularly blurred; and, worst of all, the impressions of minute determinate objects would not be superposed. Even in this adverse case, however, the elements would be present for the draughtsman to reduce them to a coherent whole. But, on the contrary, the running of a single line, all that I advocate at present, embracing a considerable distance on each side of it, would give at once data for a very presentable map of the surface of the earth involved, and this map would readily lend itself, through the labors of the draughtsman, after having been printed in the manner described, to the refinements of being photographed or lithographed as a whole. Of course, at its inception, such a map would be entirely destitute of exact indication of vertical traits, such representation as was made of them by photography depending entirely upon the effect of perspective.

It should be obvious that, instead of running a traverse line by the method hereinbefore described, in which every position of the camera, supported by the balloon, is referred to directions and distances measured on the ground, it is possible to run a traverse line by a looser method, by means of balloon work alone. With a balloon always at a fixed height, the scale, as has been indicated, is also fixed. Therefore, if the camera be placed successively over stations Nos. 2, 3, etc., representing disks successively placed on the ground, combining in pairs, stations 1 and 3, 2 and 4, etc., then the line can be plotted on paper, and if only its terminal points be determined, a traverse line of additional accuracy would be secured, because it would as a whole be oriented. We have, therefore, within the possibilities of this method of balloon surveying, three gradations of accuracy; first, where each balloon result is referred, for each link of a traverse line, to direct angular and linear measurements on the ground; secondly, where only the two ends of the traverse line being determined, the line is wholly

laid down by them; and, thirdly, where there are no instrumental determinations whatever on the ground, where the balloon camera does the whole work, by referring it to bright disks placed conveniently on the ground with reference to the topography.

I beg you to believe that I could not speak, could not indeed think, of a thing wholly untried as certain of successful accomplishment. It seems to me, however, that the plan, attempted in the manner that I have devised, subscribing to the conditions that I have sought carefully to impose, is well worthy of trial for the class of work whose requirements I have thought it might meet with the great advantage of cheapness, expedition, and picturesque delineation of certain country. I confess that I am sufficiently wedded to the belief that it would succeed, to enable me to say that I should be pleased to try the experiment with all the opportunities afforded by a centre of civilization, where are to be found, combined, artisans, material, and every facility for perfecting mechanical devices, not least among which is the counsel of experts whose assistance would render most likely, if possible, the culmination of the project in success.

SUPPLEMENT C.

[Presented by Assistant HERBERT. G. OGDEN.]

REPORT OF THE COMMITTEE ON THE CLASSIFICATION OF THE UNITED STATES FOR TOPOGRAPHIC WORK.

The committee has further considered the question of classification submitted to it, and respectfully reports that, in its judgment, no further subdivision is necessary to complete the work outlined by the Conference. It suggests, however, that the slight changes recommended by the committee on accuracy should be adopted, viz:

In Division A, coast work—Section I—change the limits from "St. Croix River to New York" to read "St. Croix River to Delaware Bay." In Section 2, change the limits "New York to Winyah Bay" to read "Delaware Bay to Winyah Bay."

In Division B, interior work, we recommend that the word "farm" be omitted from sections 1 and 2, and in section 4, "Plateau Regions of the West" should be changed to read "Great Plains of the West."

These recommendations are respectfully submitted as the final report, and the committee requests that it may be discharged from further consideration of the subject.

CLASSIFICATION OF TOPOGRAPHY OF THE UNITED STATES.

A.—*Coast work.*

(1) St. Croix River to Delaware Bay.
(2) Delaware Bay to Winyah Bay.
(3) Winyah Bay to St. John's River.
(4) Mississippi Delta.
(5) Texas.
(6) Southern California.
(7) Northern California.
(8) Oregon and Washington.

B.—*Interior work.*

(1) Rolling lands, like New England, New York, northern New Jersey, etc., excepting the mountain ranges.

(2) Flat lands, like southern New Jersey, Delaware, the Chesapeake Bay region, and the Atlantic Coastal plain generally.

(3) Prairie lands, like those of Ohio, Indiana, and Illinois.
(4) Great Plains of the West.
(5) Plateau regions of Kentucky and Tennessee.
(6) Appalachian Mountain system.
(7) Rocky Mountain system.
(8) Sierra Nevada Mountain system.

COMMITTEE REPORT ON ESTIMATED COST OF SURVEYS PER SQUARE MILE IN TYPICAL SECTIONS ON SPECIFIED SCALE.

The following table consists of the mean value of two tables of estimates furnished the committee of the whole—one by the committee on classification, to which was given the weight of one, and one by the special committee appointed February 17 to consider this subject, whose table was given a weight of two. The latter table was made up from individual estimates of eight members of the board, those members familiar with the Atlantic and Gulf coasts estimating only for these sections, and those familiar with the Pacific coast for that section.

It is evident that, owing to lack of great experience among members of this Conference in the immense region indicated, the cost per square mile assigned to these sections must be largely approximations. Closely, therefore, as the attention of the Conference has been directed to the matter of interior surveys, only time can show how nearly it has approached the actual cost in each case.

A—COAST WORK.

	Section.	System.	Scale.	Approximate cost per square mile.	Remarks.
1	St. Croix River to Delaware Bay.	New England.	1–10000	$54	Including water areas between shore lines not exceeding one mile in width.
2	Delaware Bay to Winyah Bay.	Bay.	1–20000	27	
3	Winyah Bay to St. Johns River.	do.	1–20000	25	
4	Mississippi Delta.	Delta.	1–20000 1–40000	24	
5	Texas.	Texas.	1–10000 1–30000	15	
6	Southern California.	Pacific Coast.	1–10000	37	
7	Northern California.	do.	1–10000	43	
8	Oregon and Washington.	do.	1–10000	40	

B—INTERIOR WORK.

1	Rolling lands, like New England, New York, northern New Jersey, etc., excepting the mountain ranges.	Primary.	1–30000	25	Plane table work.
2	Flat lands, like southern New Jersey, Delaware, the Chesapeake Bay region, and the Atlantic Coastal plain generally.	Coastal Plain.	1–30000	18	Plane table, with traverse auxiliaries.
3	Prairie lands, like those of Ohio, Indiana, and Illinois.	Prairie.	1–30000	20	Plane table work.
4	Great plain regions of the west.	Great Plain.	1–40000	11	Plane table work.
5	Plateau regions of Kentucky and Tennessee.	Plateau.	1–30000	15	Plane table, with traverse auxiliaries.
6	Appalachian Mountains.	Appalachian.	1–40000	17	Plane table work.
7	Rocky Mountains.	Rocky Mountain.	1–40000	13	Plane table work.
8	Sierra Nevada Mountains.	Northern half, Appalachian; southern half, Rocky Mountain.	1–40000	16	Plane table, with traverse auxiliaries.

SUPPLEMENT D.

REPORT OF THE COMMITTEE ON THE MERITS AND DEFECTS OF TOPOGRAPHICAL INSTRUMENTS.

[Presented by Assistant Aug. F. Rodgers.]

The Committee on Instruments has the honor to report as follows:

Having examined the instruments in the office of the Coast and Geodetic Survey and conferred with the mechanician of the Survey, Mr. Fischer, and having visited the office of the Geological Bureau and conferred with its topographers and made an examination of the instruments used by them, your committee has concluded that the best forms of the plane-table and alidade in present use by the Coast and Geodetic Survey are susceptible of little improvement except in the matter of weight.

There is now in the charge of the mechanician a plane-table head, No. 83, used by Assistant Donn in the survey of the District of Columbia, which, in the opinion of your committee, is as good a form as can be devised, with exceptions hereinafter noted, simple in construction and combining several recognized desiderata, viz: a broad base plate, with two tangent screws, combining adequate strength and immobility in its connection with the plane-table board.

For general use or in a very rough, mountainous country this head, No. 83, would be too heavy, unless much reduced in size, and this would involve the loss of some of its elements of present excellence, and it is thought that by reproducing the form and size of No. 83, in aluminum bronze, and with the reduced weight of an aluminum bronze board the aggregate weight may be reduced to convenient portability for all purposes.

Your committee, therefore, recommends the manufacture of an aluminum bronze plane-table head of size and form, exceptions hereinafter noted, of No. 83, and a plane-table board of full size, to be made of the same metal and with the ends semicylindrical, with a diameter of not less than 3 inches, in order to protect the rolled portions of the plane-table sheet from the short, sharp bend over the edges of the board, as is now the case in our wooden board.

INSTRUMENTS EXAMINED IN THE OFFICE OF THE GEOLOGICAL BUREAU.

The forms of plane-table used in the Geological Survey are radically different from our best instruments, especially a head and miniature board used in the traverse work of that survey. This plane-table can only be leveled by changing positions of tripod legs and can only be moved in azimuth by hand.

Still another form is known as the Johnson patent, having ball and socket motion for level and change in azimuth, but without tangent screws. It is understood that this instrument is used in plane table triangulation, and for interpolation of stations for topographic detail.

In connection with the miniature plane-table first mentioned, a small and light alidade without telescope is used, and it is understood that in the traverse work of the Survey the declinatoire or magnetic needle is depended upon for orientation and direction, and for determination of elevation, except in special cases, the aneroid barometer is used and referred at frequent intervals of time and distance to known datum-planes.

In traverse work, distance traversed is obtained from wheel measure, either by direct count of the number of revolutions of a wagon wheel or by the use of an odometer.

The odometer forms on sale up to this date do not meet with commendation from the office of the Geological Survey, and the experience of the chairman of your committee indorses the idea that there is great room for improvement in odometer forms, leaving an open field for invention with practical ideas of the adaptations of such an instrument. In its present form it must be treated very carefully as to rates of travel.

Your committee is of opinion that in rapid work, and especially in reconnoissance, a reliable odometer, in dust and water proof case, would be of great value in approximate determinations of distance.

Having visited the office of the Geological Bureau, your committee desires to express obligations to the gentlemen of that bureau for their kindness and courtesy in explaining methods and exhibiting the instruments used by them.

NEW INSTRUMENTS AND SUGGESTIONS OF CHANGES IN FORM.

From Buff & Berger's Hand-Book and Illustrated Catalogue of Engineer's and Surveyor's Instruments, published in Boston in 1890, your committee makes the following quotation for your information and consideration:

"The ta-chym-eter (tachymeter) or universal surveying instrument; the word is a combination of the two Greek words, "tachus," rapid, and "metron," measure. There are several words in Webster's Un-

abridged having the first word of the combination to signify rapidity of execution. Buff & Berger describe it as "an instrument having a level on its telescope, a vertical arc or circle and stadia wires, and as adapted to rapid location of points in a survey, since it is capable of measuring the three coördinates of azimuth, altitude, and distance." Your committee has recommended the ordering of such an instrument, or in form for attachment to an alidade, for examination. From its combination of capabilities it may illustrate the usual character of a "jack of all trades," but examination must be our best guide to judge of its probable usefulness as an auxiliary to more rapid work.

OERTEL & SON, OF MUNICH.

The Secretary of the Conference has submitted to the committee a form of level known as "Meissner's Level," manufactured by Oertel & Son, of Munich, which has the advantage of rapid adjustment in horizontal plane, by means of a single vertical milled-head screw attached to the eye end of the telescope, doing away with the old form of base-plate and four foot screws.

Your committee is of opinion that the Meissner level, as described, may be made a valuable adjunct to a party equipment to obtain more rapid results where the use of a level may be necessary.

The secretary also submitted a rough drawing and description of an instrument manufactured by Bohné in Berlin, "Taschen-Niveau," the first a German word, the last French; translated they mean a "pocket level." This instrument appears to be a hand level of more elaborate form than the lock level and has an addition of a graduated arc for measurements of horizontal angles. It seems to combine the lock level and the azimuth compass or Schmalkalder, of Coast and Geodetic Survey adoption, though represented to be without a needle.

Mr. Flemer has also called your committee's attention to an instrument called a distance-measurer, which in method serves the ordinary use of our stadia or telemeter, by having a telescope mounted upon a base along which the telescope slides, and by measurement of an angle to a distant object from each end of this base the elements are obtained for determination of the distance. This instrument does away with the necessity for sending a man with a telemeter to distant points and, in effect, enables the observer to determine distances to objects without changing his station. Of course the elements of an infinitely small base and small angle of intersection of the object determined are involved, but it is suggested that for rapid work and reconnoissance the distance-measurer may be a valuable auxiliary.

Mr. Flemer, the secretary of the Conference, has furnished rough diagrams of these instruments, and they are at the service of the members for examination.

In concluding the discussion of instruments your committee recommends as follows:

For plane-table, the present forms in use by the Coast and Geodetic Survey, and for a plane-table head, No. 83, as combining all requirements, in general form, except that there is too little space between the plane-table board and plane-table head, thus making it inconvenient to manipulate the tangent screws. This would be probably remedied by lengthening the arms which connect the movement with the board. This defect is a radical one and should be remedied in reproducing the general form of No. 83. It should never be forgotten by manufacturers that the milled heads to the plane-table tangent screw and clamps are never in sight when manipulated, and for convenient and effective use should be as large as conditions and proportions will permit.

Also note exceptions to the positions of leveling screws in No. 83. They are now above, but should be below the base plate.

The plane-table head No. 83 is also too heavy, and your committee recommends experiments with aluminum bronze for reduction of weight. That the head and board with semicylindrical edge on the sheet-rolling side be made of aluminum bronze. That the alidade be made of aluminum bronze, telescope tube, standard and ruler, and that if necessary the latter be weighted to give requisite stability. The steel rulers are objectionable on account of oxidation; even when nickel-plated the rust seeks and finds weak points to come through the plating.

The verdigris on brass rulers is a constant source of trouble in soiling field sheets. It is thought the use of aluminum bronze may eliminate the defects noted.

It should not be forgotten by manufacturers of the plane-table alidade that it is essentially a hand instrument and in Coast Survey work is usually carried in the hand many hours during each day in the field. Convenient portability by hand is therefore very important. There is but one proper hand-hold in carrying it, and that should be free from all projections. A protuberance not noticeable in the first hour of a day's work becomes an unbearable nuisance at the end of the day, and the use of such an instrument continued during a season may produce a permanent injury to the hand.

It is recommended that a circular semispherical disk of sufficient diameter, with convex surface toward the hand, in carrying the alidade, be placed around the upright or pillar, and under the vertical arc and alidade screws.

It is recommended that the alidade ruler should not be solid, but should have an open center, and that each alidade should have a space countersunk in the ruler, under the eye end of the instrument, to hold a meter scale of 1 500 meters on an 1–10000 scale, 3 000 meters on a 1–20000 scale, the meter scale to be held in place by screws, removable

On the merits and defects of topographical instruments.

at will, in case of changing scale of work; upper surfaces of scale to be flush with or in same plane with surface of alidade ruler.

From a form of alidade noted and approved by your committee, manufactured by Fauth & Co., of Washington, for the Geological Bureau, it is desired to call attention to the advantage of facing the vertical arc and vernier toward the eye end of the alidade telescope, enabling an observer to read an angle of elevation or depression without moving the alidade or changing his own position.

It is recommended that the alidade telescope diaphragm, in addition to the usual three horizontal lines for stadia measurements, should have two half lines interposed on each side of the middle line in order to double the distance of determination, the half lines not to extend more than half way from the circumference to the center of field.

A member of this Conference, Assistant R. Meade Bache, has submitted to your committee an improvement devised by him in the telemeter, and its application in coast work. Mr. Bache also presents photographs showing the manner of use, and a paper describing the various attachments.

The photographs mentioned under the textual description of the boat telemeter are submitted for inspection with this report.

As an auxiliary instrument for mountain work your committee recommends the aneroid barometer, as recently improved, desiring, however, to emphasize the importance in its use of frequent reference to known datum planes.

We recommend the trial of the odometer, and its use, if a reliable form can be found, as an auxiliary in reconnoissance and work upon the 1–40000 scale.

If the tachymeter shall be found available upon examination, it may be a valuable auxiliary in work upon the 1–40000 scale.

Your committee would recommend examination of the Meissner level, as described by Mr. Flemer.

It would be a great boon to topography if an automatic gravity level could be devised that would be superior to the present lock hand level, and yet more portable and less costly than levels of precision. It is the opinion of your committee that an automatic gravity level as suggested could be constructed, depending upon ball and socket or equivalent free motion, with a weighted pendulum below head of tripod, working on the free point mentioned and rigidly attached above to the usual form of light telescope used in spirit levels.

Subsequent to the preparation of the above report and the recommendation as to experiments with aluminum bronze as a material for plane-table apparatus, attention has been called to the inadaptability of the alloy named for alidade ruler arising from the tendency of the metal to soil the paper.

FIELD DRAWING PAPER.

The Committee on Instruments having been instructed to discuss and formulate, if possible, some practical recommendations in regard to the paper in use and furnished by the Coast and Geodetic Survey for plane-table surveys, suggests that one of the first requirements of accuracy in any plane-table survey is that the paper upon which the delineations are recorded should be as nearly perfect as possible, and certainly free from all remediable defects.

In recent years the quality and preparation of paper for field use seems susceptible of great improvement. Much of the paper found in plane-table sheets, after having been subjected to service in the field, becomes soft and fibrous, and in texture more like blotting paper than Whatman's antiquarian.

This has become a great evil in plane-table work and seems to be one universally complained of among the topographers of the Coast and Geodetic Survey.

When the aggregate cost of making any given survey contained in an ordinary plane-table sheet is remembered, and when it is remembered that the value of the survey for precision ultimately depends upon the original good quality and proper preparation of the paper, it must be apparent that it is wise economy to purchase none but the very best paper to be had and to leave no question of its best preparation uncertain on indeterminate.

Your committee, in view of the importance of this question and the length of time required for its proper investigation, would suggest to the Conference that the Superintendent be requested to appoint an office committee of field experience, to be charged with the investigation of this question of topographic field paper, and that careful experiments be made to determine the best quality and best methods of backing; the best materials, whether silk or muslin; the best adhesive materials for backing (flour paste has defects), and the best methods of seasoning plane-table sheets in the office before projections are made upon them or subjecting them to field service, so that the shrinkage of the paper after exposure in the field may be reduced to a minimum, and, further, to determine by suitable experiments and field trials the value of zilonite as a substitute for plane-table field paper. Such a committee will not be able to arrive at secure conclusions until after the expiration of one or two years, but its conclusions, if based on carefully digested facts, will be of great value to all plane-table topographers everywhere.

SUPPLEMENT E.

RULES ADOPTED BY THE CONFERENCE TO GOVERN TOPOGRAPHICAL SURVEYS IN THE SEVERAL TYPICAL REGIONS CONSIDERED.

GENERAL CONSIDERATIONS.

In the coast sections, no important modification of the methods of work and the degree of precision at present employed is practicable without material loss of accuracy, tending to lower the present standard of the charts and to impair their value to the Government and to individuals. If, in such surveys, increased rapidity or diminished cost be required, it should be attained by the omission of certain classes of detail rather than by lowering the standard of accuracy.

But in the interior, for the general purposes of topographical maps, we may reasonably relax, in some degree, the precision demanded for charts of the coast.

While gross misinformation or failure to supply information in regard to important features of the relief or routes of communication should not be tolerated in any survey of higher grade than a rough reconnaissance, it may be accepted as true that, in the present state of public needs, a map may be imperfect in the location of some natural and artificial features and yet serve ordinary purposes for which a topographic map is required, provided the general outline or skeleton of roads and streams has a good degree of relative accuracy between its different parts, and provided the critical points of the relief are correctly determined in elevation.

It is not desirable to make geographic representations for mere pictorial effects and announce the result as surveys. In all surveys for the distinctive purpose of acquiring and giving knowledge, the water courses and their sources, the drainage basins and valleys, the form and elevations of the divides, and routes of communication are the essential features, common to all sections, that should not be neglected, even when the survey is made on a small scale.

The recommendations in the following "Rules for topographic surveys," specifying the grades of accuracy which should be attained in different types of country, define the character of the surveys which, in the opinion of the Conference, best combine considerations of moderate cost, rapid execution, and usefulness for general purposes.

The members of the Conference believe that maps of a settled or prospectively valuable region made on a lower grade than that recom-

mended would not return a fair equivalent for the money expended upon them.

Should it nevertheless be necessary to make surveys of a character inferior to those that have been defined, such work should be understood and acknowledged as secondary or chorographic work.

In conformity with the resolution adopted by the Conference recommending the use of the metre as the unit of height as well as of distance, alternative expressions giving the corresponding values which in the use of the metric system should, in the opinion of the Conference, replace the customary intervals, have been added to each paragraph in which reference was made to contour intervals or precision of elevations.

The Conference is sensible that certain discrepancies are thus introduced, as when 20-foot curves are replaced in one instance by 5-metre and in another case by 10-metre curves, or when 40-metre intervals are recommended as substitutes for 100-foot intervals. It thinks, however, that the advantages to be gained outweigh nice considerations of consistency.

The fixing of intervals with the foot as the unit was largely controlled by precedent and by the desirability of preserving intervals which should be aliquot parts of 100 feet.

In making the radical change to the metric system it has seemed desirable to base our intervals, in a general way, upon a somewhat similar consideration of the 100-metre intervals as grand units of elevation, and at the same time to introduce in some cases rather smaller intervals than the 20-foot, and in other cases to give somewhat greater freedom and rapidity by increasing the interval, the change of unit enabling us to bring about these variations in a perfectly natural way. The use of the 40-metre interval in certain cases is the only exception to the rule of making the intervals aliquot parts of 100 metres. (This interval is recommended in regions where it is thought that 50-metre curves would not adequately represent the relief and where the use of 25-metric curves is not justified by the character of the country.) Even in this case the interval is an aliquot part of 200 metres, so that little inconvenience, if any, would be occasioned by its use.

It should be observed also that the adoption of the metre as the unit would in general widen the interval between the curves, reducing the number of them, but without any material loss in representation of the forms, and to some extent would lessen the cost of the surveys.

In order to render perfectly clear its views with reference to consideration of different sections of the United States, the Conference would state that the coast and the interior are at present to be regarded from entirely distinct standpoints.

Under the fundamental law and the subsequent practice of the work, the surveys of the coast have comprised fitness for purposes of navigation and for military operations. As the necessary consequence

Rules adopted by the Conference for topographical surveys in typical regions.

of the law and of the long experience of the Survey on the extended coasts of the United States, the scales appropriate to different types of coast topography have so assimilated themselves to the respective needs of each section (type, purpose, and scale according with one another) that to the mind of the expert they represent one complete and harmonious whole. In consequence of these facts the Conference has found little difficulty in the discussion of the topographical treatment applicable to the coast sections. In a word, the treatment by the Conference of the coast of the United States in establishing topographical rules for its survey, is virtually but a re-affirmation of all that in the history of the Survey has preceded this action.

The case presented by the interior is, however, entirely different. For this part of the country preëminent purpose for prospective surveys is not at present defined by law. In the absence of controlling purpose, the consideration of the question reverts to the necessity of fixing upon scale and limits of detail for different sections solely upon the basis of giving for different topographical types the maximum of information for general purposes, combined with the minimum expenditure of time and money.

While the Conference is not called upon to formulate definite purpose for such hypothetical surveys, some of the purposes which they subserve may, in a general way, be easily stated. Geological purposes they manifestly include, military purposes in a general way, if they should be so required, hypsometrical data, extent and relation of watersheds, preliminary locations of railroads and other roads, distances between towns, etc.

That such surveys would include all of these and other purposes is apparent, but only the future can decide what preëminent purpose or purposes, beyond uses generally specified, such surveys will fulfill, and therefore the Conference concludes its consideration of the surveys of the interior without attempting to define their preëminent purpose in a manner analogous to that applicable to the coast.

Division A—Coast Work.

NEW ENGLAND SYSTEM.

Section 1.—*St. Croix River to Delaware Bay.*

(1) The scale of 1–10000 should be used throughout this section.

(2) All points determined by intersection and prominent trees or other objects useful as land or pilot marks should be as accurate as the scale and material worked upon will permit.

(3) On the sea coast and on the shores of navigable rivers, projecting points of shore line, outlying rocks, and ledges should be determined with the accuracy of occupied stations or "points determined by intersection."

(4) The delineation of the low water line should be as precise as the physical conditions of the coast will permit. On moderately steep shores, where slight variations of low-water level would not produce great horizontal displacement, the low-water line may be shown with nearly the same accuracy as high water. But where the slope of the bottom is very gradual, so that slight variations of the low-water level would produce great horizontal displacement, the low-water line should be sketched freely, simply to indicate the presence of flats, or that there are channels through the flats that will require development by the hydrographer.

(5) Outlines of unnavigable rivers and ponds should be within 25 metres of their true positions, their forms being preserved as far as practicable.

(6) Narrow streams, flowing through thickly wooded valleys or wooded swamps, should, if practicable, be shown within 50 metres of their true positions.

(7) The line between hard land and marsh, when well defined, should have the same limit of error as contiguous shore line. When not well defined its delineation must be left entirely to the discretion of the topographer.

(8) Outlines of woods should not, in general, be in error by more than 50 metres.

(9) All railroads and main wagon roads should be delineated with such accuracy as the scale and material will permit.

(10) Graded roads through public or private grounds of considerable extent should have nearly the same accuracy as main wagon roads, the degree of precision to be dependent upon the relative importance of such roads.

(11) The deviation from accuracy of wood roads and other byroads at any place between their terminal points should not exceed 50 metres.

(12) Houses and barns should be shown within 10 metres of their true positions.

(13) In cities, towns, or large villages the built up sections should be indicated by shading, without showing individual buildings or accompanying details.

(14) The general shapes and dimensions of buildings should be preserved without undue attention to detail.

(15) Small or unimportant outbuildings should be omitted.

(16) In surveys on the scale of 1–10000 no fences should be omitted except those inclosing small areas around houses and barns or other unimportant subdivisions.

(17) The elevations of prominent objects, to be used as points of reference in subsequent work, should not be in error by more than 3 feet or 1 metre.

(18) The elevation of ordinary plane-table stations should be correct within 5 feet or 2 metres.

Rules adopted by the Conference for topographical surveys in typical regions.

(19) The heights of the surfaces of lakes and large ponds above mean sea level should be determined with the same accuracy as that adopted for points of reference.

(20) Within this typical area the contour interval should be 20 feet, or 5 metres.

(21) Contours may be deflected in sketching above or below their true planes, to represent particular accidents of ground, by an amount not exceeding 5 feet or 2 metres, vertically. Beyond this limit auxiliary curves should be used, if necessary.

(22) In open country, on slopes of less than 5°, sketched contours should be correct within half an interval. On steeper slopes they should be within one interval. In heavily wooded, hilly country this limit may be exceeded; but in low country, even if heavily wooded, the summits or height of land should not be in error more than 5 feet or 2 metres.

(23) Contours should cease at the edges of steep banks, and the bluffs should be indicated by hachures.

(24) In cases of importance (for purposes of navigation or future comparison), the crest lines of the bluffs should be delineated with nearly the same accuracy as the main shore line but in ordinary cases an approximate location will suffice.

BAY SYSTEM.

SECTION 2.—*Delaware Bay to Winyah Bay.*

(1) The scale of 1–20000 should be adopted for this section, except near large towns, where 1–10000 should be used.

(2) Accuracy of detail. In work on 1–10000, all details should be as accurate as in section 1.

The following paragraphs refer exelusively to work on 1–20000.

(3) Prominent objects used as signals or pilot marks should be determined with the greatest accuracy which the scale and the sheet will permit.

(4) The outer shore line should be correct within 25 metres.

(5) Inside navigable channels should be located within 25 metres; and the widths of such passages should not vary more than 10 metres from their true values when the whole width does not exceed 200 metres.

(6) Unnavigable rivers, creeks, and ponds should be shown within 50 metres of their true positions.

(7) Narrow streams through wooded valleys or swamps should, if practicable, be shown within 100 metres.

(8) In out-of-the-way marshes, broken up by numerous unnavigable creeks and openings not thoroughfares, such passages may be very freely generalized; but their junctions with main bodies of water should

be within the limit of error adopted for shore-line work of similar character.

(9) Marsh lines should follow the same rule as in section 1.

(10) Outlines of woods should in general be correct within 100 metres.

(11) Low-water line should be expressed as well as practicable under the local conditions, and generally as specified in section 1.

(12) Railroads and main wagon roads should not be in error more than 20 metres, the centers of the roads to be taken as their true lines.

(13) Park roads should have the same degree of accuracy.

(14) Ordinary byroads, wood roads, and trails may deviate 100 metres between terminal points.

(15) Houses should be shown, subject to the limitations specified for section 1, except that the limit of error (as in the case of roads) may be 20 metres; also barns, when of sufficient size or prominence to make them desirable. Special care should be taken to show isolated buildings, in the woods or elsewhere, but their positions need not be as accurately determined as in section 1.

(16) Only those fences which are notable features should be shown upon the map.

(17) Elevations, when given, should be as accurate as in section 1.

SECTION 3.—*Winyah Bay to St. John River.*

(1) Scale as in section 2 (1–20000).

(2) Accuracy of detail and relief as in section 2.

"DELTA SYSTEM."

SECTION 4.—*Mississippi Delta.*

(1) Scale 1–20000 for main river channels and 1–40000 for all other work.

(2) Accuracy of determination should be in proportion to the scale used, based upon that adopted for section 2.

"TEXAS SYSTEM."

SECTION 5.—*Texas.*

(1) Scale 1–10000 at important passes and 1–30000 on all the rest of the coast.

(2) Accuracy should be in proportion to scale, as above.

"PACIFIC COAST SYSTEM."

SECTION 6.—*Southern California.*

(1) The scale should be 1–10000.

(2) For features of the shore line and other detail the accuracy of determination should be as in section 1.

Rules adopted by the Conference for topographical surveys in typical regions.

RELIEF.

(3) Up to 500 feet of elevation 20-foot contours should be expressed, or up to 200 metres of elevation either 5 or 10 metre intervals should be expressed, according to the character of the region.

(4) Above 500 feet 50 or 100 foot contours will suffice, or above 200 metres either 20 or 40 metre intervals will suffice.

(5) The determination of elevations, when the relief is expressed by 20-foot or 5 or 10 metre contours, should be as accurate as in section 1. When only 100-foot or 20 or 40 metre contours are used, the elevations of points of reference should be obtained within 6 feet or 2 metres and of ordinary plane-table stations within 10 feet or 3 metres of their true values.

(6) When using 20-foot or 5 or 10 metre contours, the limit of error in sketching should be the same as in section 1.

(7) When only 100-foot or 20 or 40 metre contours are necessary, their deviations from accuracy should not exceed one interval (100 feet or 20 or 40 metres) when it is practicable to attain this degree of precision.

SECTION 7.—*Northern California.*

(1) Scale of 1–10000 should be used.

(2) Accuracy of detail as in section 1.

(3) Contour intervals and accuracy of contouring as in section 6.

SECTION 8.—*Oregon and Washington.*

(1) Scale of 1–10000 should be used.

(2) Accuracy of detail as in section 1.

(3) Contour intervals and accuracy of contouring as in sections 6 and 7.

DIVISION B.—INTERIOR WORK.

"PRIMARY SYSTEM."

SECTION 1.—*Rolling lands, like New England, New York, Northern New Jersey, etc., excepting the mountain ranges.*

(1) The scale should be 1–30000.

(2) Plane-table points used as signals should be as accurate as the scale and material worked upon will permit.

(3) The shore line of navigable rivers and lakes should not be in error by more than 30 metres.

(4) In work upon this scale, the topographer should show all railroads, public roads, and all other roads (except such as could not be used as thoroughfares), canals, farm-houses (when accessible), swamp areas, and wood outlines.

(5) The general characteristics of streams and ponds should be shown, without too close attention to their minute sinuosities.

(6) Conventional signs should be used for the representation of houses, villages, and towns.

(7) Barns, outbuildings, and fences should be omitted, except when the barns are very prominent or are landmarks.

(8) Elevations of main points of reference should be within 5 feet, or 2 metres, and of ordinary plane-table stations within 10 feet, or 3 metres.

(9) The contour interval should be 20 feet or 10 metres.

(10) Summit contours should be correct within 10 feet or 3 metres, and when practicable valley-floors should be correct within the same limit.

The location of intermediate contours should be as close as the scale and condition of the region will permit.

COASTAL PLAIN SYSTEM.

SECTION 2.—*Flat lands, like southern New Jersey, Delaware, the Chesapeake Bay region, and the Atlantic coastal plain generally.*

(1) The scale should be 1–30000.

(2) The amount and accuracy of detail should be the same as in section 1 of the interior.

(3) In this kind of country the representation of relief would be impracticable without great expense for leveling.

PRAIRIE SYSTEM.

SECTION 3.—*Prairie lands, like those of Ohio, Indiana, and Illinois.*

(1) The scale should be 1–30000.

(2) The amount and accuracy of detail should be the same as in section 1 of the interior.

(3) In general, the relief should be represented when practicable.

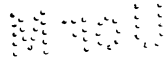
(4) The contour interval should be in general 50 feet, or 20 metres, but in special cases the topographer may use curves of smaller interval at his discretion.

GREAT PLAIN SYSTEM.

SECTION 4.—*Great plains of the West.*

(1) The scale should be 1–40000 and signals and other points of reference should be determined as accurately as the scale and the sheet will permit.

(2) All streams and dry water courses should be shown. The threads of the streams, being quite indefinite in position, may be freely generalized between the inclosing bluffs.



Rules adopted by the Conference for topographical surveys in typical regions.

(3) The bluffs should be represented by hachures and may be freely generalized, the general forms being preserved as far as practicable.

(4) Railroads and main routes of communication should be shown and should be accurate within 40 metres.

(5) All isolated houses, as indicating population and culture, should be shown within the same limit of error.

(6) Villages and towns should be conventionally represented.

(7) Fences inclosing large areas should be shown, but all other fences should be omitted.

(8) Forests, if any, should be shown, also belts of woods along water courses.

(9) Contours should be shown at vertical intervals of 50 feet, or 20 metres, and in case of sudden accidents of ground the topographer should use such contour intervals as he may think necessary.

PLATEAU SYSTEM.

SECTION 5.—*Plateau regions of Kentucky and Tennessee.*

(1) The scale should be 1–30000.

(2) Signals and other details should be represented with substantially the same accuracy and fullness as in section 1 of the interior.

(3) The elevations of points of reference should be correct within 10 feet, or 3 metres, and of ordinary plane-table stations as near that limit as possible.

(4) This section being densely wooded and very broken, the contours can only be approximate; the crests and valleys should receive the most attention, to represent their elevations and grades, without too much refinement in horizontal positions. Contours should be shown at vertical intervals of 50 feet, or 20 metres.

(5) When the plane-table can not be used advantageously, other suitable instruments may be utilized as auxiliaries. In country of this sort a survey to be made within a reasonable time and at a practicable cost must be chorographic rather than topographic; that is, the minute features of the relief must be overlooked and only the general forms represented.

APPALACHIAN SYSTEM.

SECTION 6.—*Appalachian Mountain system.*

(1) The scale should be 1–40000 and signals should be determined as accurately as the scale and material worked upon will permit.

(2) In general, this section will come under the same treatment as that outlined in paragraph 5, section 5.

(3) Railroads, canals, and all other routes of communication should be shown, the railroads and canals within 20 metres and other routes within 40 metres.

(4) Streams and ponds should be shown, when practicable, within the limits of the scale.

(5) Single houses should be shown within 40 metres.

(6) Villages and towns should be represented by conventional signs.

(7) The elevations of points of reference should be determined within 10 feet, or 3 metres, when practicable, and other stations should be determined as closely as possible.

(8) The contour interval should be 100 feet, or 40 metres, with 50-foot or 20-metre auxiliary curves, when necessary.

(9) The hill forms should be generalized, taking care that the summits and valleys be as accurate as circumstances may permit.

(10) Rocky cliffs, precipices, etc., should be indicated by hachures or shading, in addition to the contours.

ROCKY MOUNTAIN SYSTEM.

SECTION 7.—*Rocky Mountains.*

(1) The scale should be 1–40000 and the degree of accuracy should be the same as in section 6, except that in the mountains proper more generalization may be permitted.

(2) Existing detail should be shown as closely as the scale will permit.

(3) This typical section being much more open than section 6, much greater accuracy may be attained in the determination of relief. The plane-table can generally be used.

(4) The elevation of points of reference should be determined within 10 feet, or 3 metres, and the elevation of other stations should be as near this limit as practicable.

(5) The contour interval should be 100 feet, or 40 metres, with 50-foot, or 20 metres, auxiliary curves, when necessary.

(6) The summits and valleys should be represented with all practicable accuracy, but intervening forms may be freely generalized.

SECTION 8.—*Sierra Nevada Mountains.*

The northern part of this section is generally wooded and should be treated like section 6, except that the contour interval should be 50 or 100 feet, or 20 or 40 metres.

The southern part resembles section 7 and should be treated in the same way.

SUPPLEMENT F.

REPORT OF THE COMMITTEE ON INSTRUMENTAL METHODS, APPROXIMATE COST OF SURVEYS, ETC.

[Presented by Assistant J. W. DONN.]

The consideration of the resolution referred to the committee necessarily involves the subject of methods now in vogue representing the execution of topography of the highest standard compatible with the scale and purpose of the work as a basis for comparison.

It may be advanced as an axiom that the purpose in a general way indicates the scale; otherwise, given the purpose of the survey, and the magnitute of the scale is approximately suggested. In the order of classification of the general grades of surveys, those known as "critical" occupy the highest place both in the measure of accuracy and cost. Performed mainly for constructive purposes, they are of such a character as to fully subserve those purposes both for present use and future needs. In considering the cost per square mile of such surveys it is obvious that the smaller the vertical distance between horizontal contours, the greater the relative expense of the undertaking. It is safe to assume that the survey of a given area upon which contours of 1 foot (v. d.) are delineated, will cost approximately three times as much as the same area with 5-foot contours. The cultural and natural details otherwise form but a comparatively small part of the cost of such work.

In general terms it may be stated that in a survey upon any one of the scales used in critical work—1-600, 1-1200, 1-4800, or 1-5000—with elevations developed by 5 foot contours, the cost should not exceed $900 per square mile. In exceptionally difficult areas, with high and complex configuration, this would be exceeded, while upon ground simple and with low configuration the cost might not exceed $100 per square mile. All cases of large scale work, however, should be treated according to the character of locality, and it is therefore manifestly impossible to make a hard and fast rule as to cost when conditions of surface are so varied. An experienced topographer need not be greatly perplexed to determine the question of cost after having obtained a comprehensive view of a prescribed locality; but to say in advance of such action what should be the expense of such a survey, would be as difficult and unreliable as a weather forecast six months ahead of time. But special cases of very large scale critical work may be relegated to a place outside of the subject under consideration.

The usual scales of work—1–10000, 1–20000, 1–30000, 1–40000—are applicable to the general purpose of delineating the topography of a country. In the execution of accurate surveys, each has a locative value and a delineative power commensurate with its place in a definite system of measurements. While it is apparent that a scale of 1–10000 may be used in a locality where a comparatively full and accurate survey could readily be obtained through the medium of the smaller scales, without loss of time or increase of cost, it is equally apparent that the smaller scales could not be made to measure up to the possibilities of the former. In a country of varied configuration and largely diversified detail, so full as to justify all the care and refinement possible with the larger scale, there may occur a very considerable tract of marsh land, sandy waste, or wood land, virtually barren of topographical details. Uniformity requires the extension of the large scale work over the whole area, although the smaller scale would completely fill all the needs of these almost featureless parts. But the combination of these areas, embracing the largely detailed and the featureless within the same project, serves the purpose of decreasing the cost of the whole. This shows that the scale does not, within any reasonable degree of certainty, indicate the cost. All things being equal, the purpose in a general way defines the scale, and the scale the cost of the survey. But here the question of personality comes in as an important element of uncertainty; for of two individuals, A and B, A finds no difficulty in accomplishing a given result in a specified time, while B, from inherent difference of temperament, mental or physical disqualification, may not, with the expenditure of his best powers, be able to reach the standard of A. This differentiation of personal attributes or conditions enters, unfortunately, into the question of expense. In quality of work, B may be quite equal to A, but in quantity far inferior. It follows, if this be so, that as topographers must differ very much in respective excellence the variation among them in judgment in this matter must take a much wider range than that in the case cited. It becomes thus apparent that differences in judgment, as applied to determinations, even within any given scale, are an element of unassignable difference in value.

For the purpose of eliminating as much as possible error growing out of difference in judgment among men as applied to topography, reliance must be placed upon a hand-book for topographers, such as is in contemplation as the concluding portion of the labors of this Conference.

Taking the various conditions cited above and the differences between men in skill, physical qualities, and judgment, the difficulty of determining the exact cost of any given work is very great, that is, if the area to be surveyed is large and varied and the time limited, requiring the united efforts of several topographers to accomplish it.

The instruments used have but small part in altering the relative

conditions among a number of men. By a combination of the best methods of instrumental work and the selection of topographers according to their several abilities, the cost of work may be materially lessened without loss of accuracy, but the degree of economy still remains an unsolved problem, for it must not be forgotten what a large part climatic conditions may play in the matter. To illustrate the effect of this, reference is made to the survey of Mount Desert Island. In the first year of that work, a season of four months' duration, one-fourth of the time was lost by fog and rain. In the second year a still longer time was involved, and in the third in one month alone there were twenty-two days of fog, when nothing could be done in the way of field progress. It is hardly necessary to say that the cost of that work was largely increased by the vicissitudes of weather.

For the work of the future, the consideration of which is placed upon us in compliance with the instructions of the Superintendent for a statement of "Methods by which work may be rendered more rapid and less expensive without material loss of accuracy," the following statement is presented, beginning with a classification of the several scales of topographical work, their sphere of usefulness as to locality and adaptation to the purpose of the work to be performed, and an approximate average cost, in which estimate due consideration is given to the several retarding influences heretofore mentioned.

Four orders of scales are given, each embracing two classes or variations of country.

Order I.	Class A	Regions of large population, high configuration or relief, largely varied cultural and natural detail. Scale, 1–10000. $60 per square mile.
	Class B	Regions of similar character as to population and detail, but low relief. $50 per square mile.
Order II.	Class A	Regions moderately populated, high relief, but of inconsiderable cultural and natural details. Scale, 1–20000. $40 per square mile.
	Class B	Regions similar as to population and details, but low relief. $30 per square mile.
Order III	Class A	Regions of rolling prairie lands, moderate as regards population and details. Scale, 1–30000. $15 per square mile.
	Class B	Regions described as plateau timberless, sparse population, few natural details. $10 per square mile.
Order IV	Class A	Regions of grassy lands, or lands not susceptible of much cultivation, small areas of timber. Scale, 1–40000. $8 per square mile.
	Class B	Arid lands or sandy plains, mountainous regions, and flat forest lands. $4 per square mile.

The above estimates embrace only the cost of maintaining parties in the field while executing the triangulation and topography. The total cost, including the salary of the chief of party would increase the amounts from 25 to 50 per cent.

In each of these classes there are vast areas where climatic conditions vary greatly from great heat to long continued intense cold, excessive rains, and almost entire absence of rain.

By curtailment of details of minor and comparatively unimportant characteristics, the classes under Order I may readily be placed under the terms as to cost of the classes under Order II. There need be no decrease of accuracy, but less completeness as to details. The important desideratum, of course, in all classes is accuracy in as large degree as the scale of the work will permit. In the fourth order great generalization of details will be necessary, especially in delineating the relief.

A rule that may be applied to the subject is that the lower the class the smaller the degree of refinement possible and the more infrequent the recourse to instruments of precision.

The limit of error should never exceed the capacity of the scale. In other words, each feature indicated should be truthfully represented; *i. e.*, while the minor details of a ridge or valley may be freely generalized, its general form and the direction of its axis should be correctly given. In like manner the outlines of a lake or pond should represent its general relative proportions and location.

ON INSTRUMENTS.

The capabilities of that instrument of instruments, the plane table, and its unequaled usefulness in every order of work named above are fully understood by all the topographers of the Coast and Geodetic Survey. As an instrument for rapid and accurate determination of position, it stands superior to all others. Its auxiliary, the telemeter, in facilitating the location of details not readily determinable by intersection, and the combination of the two with the Y level and rod, is all that can be desired in large scale work. In the scales of work designated by Orders III and IV other auxiliaries may with advantage be used. The small railroad transit with vertical arc is an invaluable instrument in running traverse lines in regions of timbered lands where points of observation for plane-table stations are infrequent. The sextant also has its use in minor traverses for the location of road junctions, the general course of streams and their confluence with others, and other objects more or less hidden from view of the plane-table. The French water-level is most excellent for road profile and contour sketching and the Locke level in a less degree can be used to considerable advantage. The small traverse plane-table may be used in small scale work and secure good results. Other very valuable auxiliaries recommended are the distance measure of Oertel & Sons (Munich) and the tachygraphometer, both of which will largely aid in the production of rapid and economical work.

An important reduction in the cost of topographical work may be effected by placing the secondary and tertiary triangulation in the hands of the topographer. A large number of points quite useless to the topographer are determined by parties unfamiliar with topograph-

ical methods. The cost of such triangulation being charged against the topography of the locality, economy can surely be gained by uniting the two under one chief of party. No appreciable delay would be caused in advancing the topography and no points would be located and determined that did not bear a closely defined relation to its needs.

The recently improved aneroid barometer can sometimes be used advantageously, but it is extremely doubtful if it will be found judicious or economical in topographical work, excepting in cases of extreme difficulty. In a long discussion of the subject of barometric measurements of heights, Mr. G. K. Gilbert, of the Geological Survey, notes the effect had upon the barometer in high winds. In a series of observations made upon Mount Washington he detected some anomalous fluctuations which he "was enabled to trace to the influence of the winds upon the tension of the air in the observatory, and this influence was found to be so great during the prevalence of gales as to vitiate the record of the barometer. The error amounted in some instances to the one hundred and eightieth part of the atmospheric pressure and affected the determination of altitudes by more than 100 feet."

The influence of humidity and temperature and the errors of observation all make up a series of unsatisfactory conditions, not easy to eliminate by the best process known to practical men.

Mr. Gilbert, in his conclusion, states that—

> In any survey which is based upon triangulation, the points occupied are intervisible, so that if their distances are not great it is possible to ascertain their relative altitudes by means of vertical angles and with a degree of accuracy not attained by the barometer.
>
> The topographer is able to compute the relative height of all points visible to him from any station, provided their distances become known, by measuring the angle of elevation or depression which they subtend; and, since other stations of his system are always included among the points of observation, he is able in this manner to carry through his field a connected system of altitude determinations.
>
> When, in the progress of geographic refinement, the stations of the topographer approach so near to each other that the precision of the measurement of altitudes by angulation becomes equal to the precision obtained by means of the barometer, barometric hypsometry receives at once a formidable competitor. Indeed, it encounters an invincible antagonist; for the expense of reading vertical angles, when it is performed as a mere accessory to the ground work of the topographer, is notably less than the expense of transporting and observing barometers. The most thorough geographic work will therefore dispense altogether with the barometer.

When, in connection with this statement, the practical method of the determination of altitudes by the plane-table alidade is considered, it will be seen how expensive and slow are the methods of barometric measurements. From any two stations forming a base of proper length a large number of altitudes can be readily determined. With the plane-table, therefore, a topographer thoroughly familiar with its

capabilities, is never at a loss as to the means by which any difficulty encountered is to be overcome.

The camera, in connection with the plane table, may be occasionally usefully employed in the representation of the profiles of mountains and hills in bold relief. It can not be said that its sphere of usefulness is in any case so great as to make it a formidable rival to the plane table. While its delineation of clearly discernible topographical features may be more readily obtained as a picture or series of pictures as seen by the eye, the exact projection of those lines of sight making up the picture upon a geographic plan would be a slow process, and one inferior in precision to the lines of intersection showing the same plan as drawn upon the plane table. And when the obscure or non-discernible features of a locality are borne in mind, and there are but few localities where such are not found, the limitation of the camera must be fully seen.

Applying the remarks of Mr. Gilbert, previously quoted, in regard to the comparison of barometric and angulated altitudes, and changing expressions to suit the relative influences of the two instruments, we may say: When in the progress of geographic refinement the determining lines of the alidade drawn upon the plane table approach so near the lines of sight, as seen in the pictures represented upon the photographic plate, that the precision of their intersections becomes equal to the precision obtained by means of the camera, photographic topography encounters an "invincible antagonist;" for the expense of drawing those lines in the field, where it is a mere accessory of the general work of the topographer, is notably less than the expense of producing the pictures of the locality, the development of its lines from camera stations, and their projection to scale in a geographic plan; to which may be added the surely attending circumstance that a large amount of detail is beyond the reach of a camera, excepting by a multiplicity of views from a large number of stations, the projection of which to plan would be conducive to delay and confusion.

We may rest satisfied that in the plane table we have the highest type of an instrument for topographic work yet devised. In it we find simplicity combined with precision, rapidity of execution with economy of labor, and adaptability of means to the end to be attained.

In the accomplishment of topographical work of minimum expense, combining accuracy with rapidity of execution, it is unnecessary to look beyond this instrument for the means to reach the desired result. The proposition may be stated thus:

Given the character of a locality, its relative relief, its cultural and artificial features in terms as stated in the arrangement of classes, and the cost may be approximately expressed. If it is desired to conduct an inexpensive survey over a country classed under a high order, the method of accomplishing the desired result will be apparent. Accu-

racy in all prominent features must be first attained, and then the degree of refinement in the less important details must give way to the exigencies of the case. Often it may be necessary to ignore many details to keep within the limits of available means.

An estimate for the approximate cost of topographic work in the typical regions is herewith submitted; the figures include triangulation and exclude salaries of officers.*

*Refer to Supplement C for approximate estimates adopted by the Conference.

SUPPLEMENT G.

FACTS AND POSSIBILITIES IN TOPOGRAPHIC WORK.

[By Assistant Aug. F. Rodgers.]

The evolution of modern navigation from the old time sailing packets, plying between European ports and those of the United States, often blown helplessly out of their true course by adverse winds for weeks at a time, up to the present "ocean greyhounds" rushing through the sea on schedule time with almost the speed and precision in arrival and departure of railroad trains, is due in no small degree to the excellence of modern charts and the precise knowledge placed in the hands of the navigator through the Coast Survey of the United States and kindred surveys abroad.

Carefully determined positions of light-houses, of headlands, of outlying rocks, and of coast line; careful observations to determine the magnetic declination of the compass needle, that mainstay of the mariner, his guide over the pathless ocean, careful observance and record of tidal phenomena all along our coast, and exact methods of triangulation on which to base our topographic and hydrographic surveys, were all necessary, before safe and reliable charts could be placed in the hands of the mariner to enable him to properly guard the human lives and valuable cargoes dependent upon his intelligent care.

A "pretty good chart only" for the purposes of rapid steam navigation, where a ship approaches or runs along the coast at a speed of a mile in three minutes, would be as little acceptable or useful to the modern mariner as "a pretty good egg only" to the average man—an offense in both cases.

Our topographic maps along the seaboard, made for chart purposes and for military use, have been made to show in detail contours of level, summit elevations, the positions and relative size of rocks lying off or along the coast; in a word, have furnished truthful topographic delineations of the lands adjacent to the seaboard, including all cadastral or cultural features, combining results of value to the mariner, to military defense, to the farmer, and the land owner.

Made as they have been made, our surveys have furnished a basis of truth, a solid foundation at least, to build county and State maps upon, along the whole seaboard of the United States; and in surveys of the interior, wherever our geodetic work has been carried it is accepted, and it may well be, as unquestioned authority upon which to base State work.

Facts and possibilities in topographic work.

If the topography of the Coast and Geodetic Survey should be carried further inland, the work already done will afford a starting base for future operations, but the special conditions of exactitude and detail which govern the seaboard work do not there exist.

As an illustration of the difference of conditions, there are still great areas in the great West, west of the Rocky Mountains, so sparsely settled that at this day the treatment of cadastral or cultural features need have no place in the discussion of questions of proper scale or time or method in making surveys of them.

Many of these areas are rainless as compared with eastern areas, and some of them nearly waterless, and thus not open to ready settlement, but the valleys and plains of most of these areas would "blossom as the rose" if moderate irrigation could be provided.

The hardy growth of sage brush of various kinds, covering millions of acres of wild lands in the public domain of the United States, seems from repeated experience in many different localities to indicate a latent strength and fertility in the soil that water and the plow may develop into rich arable land.

The people of the United States need never be hopeless of these lands of theirs after the recorded experiences of the French Government and engineers in bringing areas of the Saharan desert under cultivation, through abundant water furnished by artesian wells.

The areas spoken of are cut frequently by intercepting ridges of high and rock-ribbed mountains, with elevations running up to 10 000 or 12 000 feet above sea level, their summits covered with snow for several months in each year.

These areas are a part of the great farm belonging to the United States, and if our population increases for the next one hundred years as it has in the past, they must all be brought under occupation; and as the crowding of areas, now well filled by population, becomes more and more felt, money must be spent and experiments made to prove the value of these lands for homestead purposes.

In this view alone it seems evident that a certain amount of defined knowledge in regard to relative elevations, present natural roads, mountain passes from valley to valley, water courses where they exist, and, in a word, all information which may lead to a determination of the present and prospective values of these wild lands, would be of great use to the Government.

It seems further evident that the survey required for the purpose indicated might be on quite a small scale and much more generalized as to details than would have been either practicable or profitable upon the seaboard of the country.

It is believed that even such generalized surveys would be very greatly enhanced in value and without material increase of cost by basing them always upon carefully determined triangulation points,

thus affording the means of joining intelligently and accurately at some future time successive areas at first unconnected.

These stations of triangulation once occupied and marked would be available for future work for all time, where settlement should introduce new features and develop necessity for a more complete topographic survey.

The triangulation would not need to be elaborate, but rather of a quality to carry with it constant evidence of the degree of accuracy attained, and thus avoid with certainty the element of indefiniteness.

This would be accomplished by the occupation of all the stations in any main scheme—thus checking the filling of triangles—and by double determination of all inferior and subsidiary stations.

These determinations by theodolite would serve as a basis for locating topographic work, even if detached, in such a way that when desired it could be connected intelligently with other detached areas.

A theodolite of 10 inches diameter reading to 3 seconds would be quite equal to the requirements of the triangulations intended to be outlined.

A plane-table for topographic detail, with an odometer and several aneroid barometers as auxiliaries, would in some cases facilitate progress.

Absolute elevations at distances from the seaboard could be determined trigonometrically and from known datum planes. The barometer, if carefully used in settled weather, would furnish approximate elevations.

In 1875, with mercurial barometers, starting from the datum plane of the Central Pacific road at Redding, Cal., by synchronous observations, a Coast Survey party obtained the elevation of Strawberry Valley at the foot of Mt. Shasta, and by similar observations at the summit of the mountain and at Strawberry Valley on two days at stated hours, 9, 12 and 3 p. m., the elevation of the summit was approximately determined to be 14,440 feet* above sea level, with a plus or minus correction of 50 feet.

With the admission that results proportionally close for general contours in a preliminary survey would be satisfactory, it is evident the barometer could be used to advantage.

Of course in unsettled weather the barometer is not to be depended upon for elevations, and the "pumping of a barometer" as sailors call it in a storm, has been noted many times, and especially in narrow gorges in California, when with every blast of wind succeeded by a momentary lull, the index of the instrument would respond, indicating by its rapid motion increased and suddenly diminished pressure of the atmosphere; but this does not militate against the use of the barometer as an auxiliary for elevations, under proper conditions.

*An approximate determination by railroad levels and vertical angles gives 14,350 feet.

Facts and possibilities in topographic work.

It has been shown that the work done upon our seaboard by the Coast and Geodetic Survey has been generally first-class, and that it could not otherwise have met the requirements of modern navigation; leaving out of consideration the advantages in such complete surveys to studies of military defense, and the incidental advantage to the farmer, the landowner, and the great land traveling public of our country. It has been shown also that surveys with equivalent information of interior regions, largely the property of the nation—a part of the national domain about which little is authentically known and where authentic information must be desirable to the owner, just as the possibilities and the capabilities of outlying and unimproved lands of the private farmer would be a valuable demonstration to him—could be obtained at little expense compared with the cost of surveys of seaboard areas.

There are areas yet unsurveyed which would require much less detailed representation than the areas adjacent to the seaboard, but more than the unsettled areas of the great West; and a wise discrimination will be necessary in making recommendations between these classes as to the proper scale for fieldwork, the amount of detail that should be required, and that just expenditure for which a truthful equivalent in results may with certainty be rendered to the nation.

Unfortunately, the appearance of a map is not always evidence of authentic value as to methods or results in the survey upon which it is based; and unless its groundwork and foundation be true, and may form a useful basis for development, the money and time expended in its decoration is only like expensive ornamentation on a rickety house built upon a frail foundation.

SCALES OF TOPOGRAPHICAL SURVEYS OF FOREIGN GOVERNMENTS AND THE UNITED STATES.

Great Britain	1-500 for cities and 1-2500 for country in general.
France (formerly)	1-2000 and 1-5000 for fortified places and vicinity. 1-4000 for country in general.
France (now)	1-10000 for country in general and 1-20000 for mountainous districts.
Algeria	1-40000 in the northern parts and 1-100000 in the southern parts.
Belgium	1-20000.
Denmark	1-20000.
Holland (old survey)	1-25000.
Holland (new survey)	1-5000 (1874).
Sweden and Norway	1-20000 for settled districts and 1-50000 and 1-100000 for the northern regions and high mountains.
Germany	1-25000 in general and 1-10000 special localities. 1-500, 1-1000, 1-2500 for engineering purposes. 1-125, 1-250, 1-500 for cities and vicinity.

Austria	1-12500 for special localities and 1-25000 in general.
Switzerland	1-25000 in general and 1-50000 for mountainous districts.
Italy	1-25000 in general. 1-50000 for mountainous districts. 1-10000 for certain seaports and vicinity.
Spain	1-25000.
Portugal	1-50000 and 1-100000.
Russia	1-21000 for settled districts. 1-42000 for northern provinces and for (also 1-84000) the great steppes of the east.
Asiatic Russia	1-17000 to 1-84000.
Roumania	1-50000 and 1-100000.

UNITED STATES GOVERNMENT SURVEYS.

Lake Survey by the Engineer Corps U. S. Army	1-10000
Coast and Geodetic Survey	1-10000 1-20000 1-40000
Coast and Geodetic Survey, special surveys	1-600 1-1200 1-4800, etc.
Geological Survey	1-31250 1-45000 1-62500 1-125000

SUPPLEMENT I.

REPORT OF THE COMMITTEE ON "METHODS OF UNITED STATES AND FOREIGN GOVERNMENT SURVEYS."

[Presented by Assistant W. H. Dennis.]

Resolved, That a committee of five (5) be appointed by the chairman, to report on the methods of making topographical surveys by the several Departments of the United States and Foreign Governments, and to recommend such changes or improved methods, if any, as they may deem of advantage to the work as now executed by the U. S. Coast and Geodetic Survey.

Your committee, to whom the above resolution was referred, beg to state that the subject has been quite exhaustively investigated, considering the limited time at its command, and to submit the following papers as its report, viz: Critical surveys for special purposes in the United States by Assistant J. W. Donn; topographical surveys in the United States and in Italy by Assistant D. B. Wainwright; surveys in England and France, and notes on surveys in Belgium, Denmark, Holland, Portugal, Roumania, Russia, Spain, Sweden and Norway, by Assistant W. C. Hodgkins, and on Germany, Austria, and Switzerland by Assistant J. A. Flemer. Mr. Flemer also submits a paper on photogrammetry. On this subject a subcommittee was appointed, who

thus far have been unable to make the field experiments necessary for a full report. It is, however, the opinion of the committee that photogrammetry would be of little or no value in making surveys of exact scale.

UNITED STATES COAST AND GEODETIC SURVEY.

In a paper on cartography submitted by Mr. A. Lindenkohl of the Coast and Geodetic Survey we beg to refer with entire approval to the statements on page 603 relating to linear measure and to the plane of reference, and from the investigations your committee concludes that it is unable to recommend any method of making topographical surveys that would be an improvement on that now in use in our own service. Should we however be called upon to make surveys over more extended areas, in mountainous countries, and on smaller scales, we believe that the use of the tachymeter attachment to the alidade; the distance measurer by Oertel & Son, Munich, and the improved aneroid barometer would be of great advantage.

CRITICAL SURVEYS FOR SPECIAL PURPOSES.

[Presented by Assistant J. W. Donn.]

Surveys of this character have been undertaken from time to time by the Coast Survey during the past thirty-five or forty years. In many instances the work has been done for strictly comparative purposes, in the interest of a scientific study of the laws governing the formation of shoals, the dynamic action of wave motion and tidal currents in degrading or building up the shores. The survey of Sandy Hook, Rockaway inlet and beaches, Coney Island and Vineyard Sound, Hatteras inlet and cape, Cape Fear river entrance and the Mississippi delta are among the localities where special resurveys have been required because of ceaseless fluctuation in their character and conditions.

The special surveys of New Haven, the shores of the Delaware at Philadelphia, the Taunton river, Baltimore harbor, and others, are instances in point of work done largely in the interest of improvements of harbors and harbor approaches.

The survey of Portland city and harbor which was urgently called for during the superintendency of Prof. Benjamin Peirce, was made under a special appropriation authorized by the municipal authorities of that city. It had for its object the improvement of the water front along Fore river (the Harbor proper) and the Back Bay, and to secure data to enable a commission to make a scientific study of the question involved, viz: a large reduction of the water area of the Back Bay or basin which at low water presented a vast expanse of unprofitable flats through which a narrow winding stream made its way. The city au-

thorities deemed the subject of such importance as to devote $15,000 to a most accurate survey of the whole area covered by the city, Fore river, and the bay above mentioned.

The work was begun by the Coast Survey in the summer of 1868, and the methods adopted were quite similar to those usually practiced by civil engineers, with the exception that a plane table was used for the determination of the relief indicated by contours of 6-foot interval, instead of a transit. These contours were run in by level determination of cross-section stakes, distances measured by steel tape and plotted upon plane table sheets.

In 1869 the survey was continued, the summer months constituting the season of practical work. The manner of prosecuting the survey was essentially changed from the method used the previous year. The plane table, in its complete adaptability to the highest as well as the lowest orders of surveys, was used to the fullest extent of its locative power. The scale of 1–1200 = 100 feet to the inch, represented in its full plan every cultural detail in the city and suburbs and every feature of the relief capable of being expressed in terms of the 6-foot contour. Instead of cross-section stakes, as in the previous summer, each contour was traced by the level rod directed by the level, and its distance from the station of the plane table determined by steel tape measurements. Railroad curves were located by plane table intersections, as were the corners of houses, angles of streets, curb and building lines.

In the survey of Craney Island, Virginia, made in 1874 by request of the Ordnance Bureau, U. S. Navy, an advance was made in the method of measurement by the free use of the telemeter. The scale of this survey was also 1–1200, but the contour interval was 1 foot. How efficiently the telemeter was found to be applicable to the development of the relief by that small interval is shown in the sheet of that survey.

The most extensive survey on so large a scale as 1–4800 ever performed in the United States was carried over the area of the District of Columbia, about 60 square miles, between the years 1880 and 1891. The methods of work used for the Craney Island survey were adopted. Based on a sufficiently minute triangulation, the plane table and telemeter and the wye level and rod were used for all determinations of details. The relief was elaborately indicated by contour intervals of 5 feet. The datum plane furnished by the Engineer department of the District of Columbia was that on which was based all the levels made for grades of streets and sewers in the city of Washington. The survey being especially made for the purpose of extending streets and avenues beyond the city limits, and involving the whole subject of future grades when those extensions should become necessary, it was entirely appropriate that the levels of the survey should conform to the datum given.

From this datum along all roads, avenues, and railroads, lines of levels were run, and after careful checking in the usual manner benchmarks were placed in positions convenient to all parts of the field.

On methods of United States and Foreign Government Surveys.

Where roads were infrequent, lines were run across country so that the sum total of all the bench-marks established for purpose of contouring ran high up into the thousands. The plane-table stations were established so as to easily reach every part of the field and so close together that it was generally possible to encompass the distance from station to station when intervisible, by readings within the range of the telemeter. The mode of procedure was as follows: The plane table having been placed in position by a graphic solution of one of the several methods of the three-point problem, the level in the meantime having had its elevation above a near bench-mark determined and the target of the level rod fixed so as to give the bottom of the rod when its target was in the line of sight with the level, the measure of a contour interval above or below the bench-mark, the party was in readiness for making an advance movement. The rodman then began his journey along the imaginary horizontal line presenting his rod vertically held for the observation of the leveler at each noticeable change in the configuration of the ground, and when the target had found its place in the line of sight in the level, the telemeter rodman presented his telemeter held as nearly as practicable perpendicular to the line of sight from the alidade, for the reading of the distance between the plane-table station and the level rod when held at the point in the contour. This being read and plotted on the plane-table sheet, the rodman advanced along the line as far as the distance could be conveniently read from the plane-table station. Generally two and sometimes three contours were thus run from one level station as far in both directions as the scale of the telemeter would safely permit. After the limits of the distances as read from the plane table were reached, a turning point below the elevation of the level for higher or lower contours was fixed and the level moved to another position and its elevation determined.

In this manner many thousands of miles of contours were run over the area of the survey.

The plane-table operator in this work had no idle moments, his attention being constantly fixed on the movements of his leveler and rodmen, excepting when the new position of the level was being taken. Thus his eyes and hands were busy in drawing lines of intersection, determining the numerous other details, and drawing the permanent lines of his work.

METHODS OF TOPOGRAPHY IN THE UNITED STATES.

[Presented by Assistant D. B. Wainwright.]

"Quot homines, tot sententiæ"—many men, many minds—may well be taken as the text of any account of the topographical surveys of the United States.

One of the most troublesome questions which arise in treating the subject is to give a good definition for the words "topographical survey." Anyone who may go out and make a sketch of a certain area, jotting down the relative positions of certain features of the earth's surface, may return with the idea that he has made a topographical survey. Another with more purposes in view, more requirements to be satisfied, will name the foregoing a sketch, and to fulfill his wants will use a compass and some simple means for measuring distance. With these he will determine a number of prominent features, sketch the intervals between them, plot the whole to scale on a sheet, and, unless he is a man of rare modesty, the words "topographical survey" are sure to appear conspicuously in the title.

And still another, from his point of view, will call the preceding result a reconnaissance, and will proceed to map the country with more refined methods, employing a greater number of instruments, and obtaining a greater number of details.

And so we advance in an ascending scale, until the large cadastral surveys are reached, where even the ground plans of small houses are faithfully shown, and the relief is expressed by contours of small interval. The varieties of instruments used have been as numerous as the different classes of work performed.

The simplest instrument that I am aware of was employed far back in the thirties. In this case, I am credibly informed, the topographer traversed some hundreds of miles of New Jersey roads, using the stride of his horse for measuring the distance, and, having on the back of his left hand a quadrant marked off in ink, he determined the angular turns by sighting his right hand over this most novel graduation.

This instrument, I believe, was only employed by its inventor, but is mentioned here, not only because it is unique on account of its originality and simplicity, but it plainly exemplifies the fact that a Coast Survey officer can use "cheap" instruments when necessity requires him to give cheap results.

From this simple type there is a range of choice through many forms of varying complexity, until we arrive at the modern plane table as manufactured for the Coast and Geodetic Survey, which, while it is still susceptible of further improvement, stands in my estimation preeminent as the instrument for the topographer.

The military expeditions sent out by the Government in the early part of the century into the then unknown West, all obtained in their explorations material for charting the country traversed. With long

distances to pass over and great hardships to contend against, the instrumental work was necessarily of the crudest sort.

The geological reports of the various States all have maps accompanying them. These, however, were mostly compiled from land surveys, and the geologists almost invariably complain of their inaccuracy, and urge the necessity of regular topographical surveys.

The surveys of Hayden, Powell, King, and Wheeler were all intended to cover in a short space of time large areas of country of which little was known, and a large portion of which consisted of mountains of the most rugged description. The details were determined from meander lines, generally controlled by triangulation, and the elevations attained by barometer.

The survey of the Adirondack wilderness in New York, by Colvin, was made in a more precise manner. With a base derived from the triangulation of the Coast and Geodetic Survey a scheme was developed covering this region with a number of well-determined points. The observations were made with a theodolite, and careful attention paid to details. The prominent peaks, summits, ridges, valleys, and lakes were determined by intersections from the triangulation stations, and those of minor importance sketched in.

For ascertaining the heights, and plotting the relief, a mercurial barometer was employed—the aneroid proving too unreliable. Dudley Observatory was used as a point of reference for the whole survey, and numerous base stations were determined by synchronous observations. These stations were situated at the foot of the mountains, and served to check the observations taken at a greater altitude, when local atmospheric disturbances rendered a direct comparison misleading.

An error of 70 feet, Mr. Colvin states, might have crept into the determination of some of the peaks but for this precaution. It was also noted that the mountain-locked valleys were peculiarly subject to irregular changes, local in character.

The inventive faculty seems to be well developed in the true topographer; and it is hardly a source of wonder when we recall the endless variety of difficulties he is constantly meeting, requiring prompt solution, and which are only overcome by a resort to clever devices. One instance of this talent has already been given. Mr. Colvin illustrates his report with several examples.

The height of some inaccessible peak being desired, it was determined from one of greater altitude by occupying a point on the side of the latter where a telescopic level would indicate that a horizontal line would pass tangent to the top of the former. The distance being known from intersections, the combined correction for curvature and refraction is added to the altitude of the point of observation as given by the corrected barometric reading, and the result will be the desired height of the distant peak.

In the case of a lake so hidden away in the forest that it was impossible to fix its position by ordinary means, a calm night was chosen, and observers being stationed at known and commanding points a rocket was fired from the edge of the lake at a given signal and observed upon with the instruments. Should this lake also have such an extent of shore line as to make it requisite to determine more points along its borders, Mr. Colvin would obtain these by having recourse to a modification of the old expedient of boat and mast, so familiar in Bowditch for a harbor survey.

Selecting a tree growing on the edge of a semicircular bay, a signal is set up at its foot. Another is placed 52·4 feet higher up on the trunk. Taking a sextant and setting the vernier to read 3°, a search is made along the shore of the bay until the upper, as reflected, coincides with the lower signal; this point will then be 1000 feet distant from the tree. From this base the triangulation proceeds.

The Engineer Corps of the U. S. Army seems to have borrowed the traditions of their English brethren of the Ordnance Corps. On the Survey of the Northern and Northwestern Lakes, conducted by the Corps of Engineers, the topography was executed in substantially the same manner as the English Ordnance Survey, with this exception: the distances on the meander lines were measured by means of stadia. Based on a rigid triangulation, the topography was obtained by setting up a theodolite at one of the stations and running a traverse line to another triangulation point, measuring the angles and distances on the way to such details as were visible from the line. The probable error for any one of these lines was found to be 1 in 649.

The contours were drawn from heights determined by vertical angles. The interval was from 10 to 20 feet. The scale 10000.

Here it seems pertinent to inquire into some of the causes which led the Ordnance Corps to reject the plane table, since their great survey has exerted a powerful influence on the choice of methods elsewhere. With the whole of Europe unanimous in favor of the plane table, why should Great Britain discard it? The answer is readily found when we call to mind the climate of those islands, which is proverbial for its inclemency. With a survey executed on a large scale, with numberless distances to be plotted, it is a serious objection in such a country to have to depend, as is necessary with the plane table, on a material like drawing paper, which expands and contracts according to the moisture in the atmosphere, not equally in all directions, for that would be merely a change of scale, but about one-fifth more in length than in breadth.

In our climate, if due care is taken as to the exposure of the sheet, and on work well controlled by triangulation, this contortion is of less importance. However there are always some days in a season when the conditions would be favorable for plane-table work were it not for the dampness in the atmosphere. This time we utilize in erecting sig-

nals, sketching, etc., but in Great Britain the number of such days is so out of proportion to the number of good days, that the use of a plane table with a sheet made of backed paper is out of the question. Happily we seem now in a fair way to obtain a substitute for paper, and thus get rid of a serious objection to the use of the plane table in all climates.

As to the comparative cost of the two methods, the testimony is in favor of the plane table. It is a specious argument to estimate the cost of topography per square mile in one country by one method and compare it with the cost per square mile in another country by another method. The conditions may be very different. A favoring climate, a simple terrene, and a lack of check work may all make the more expensive process appear the cheapest. But we have in this country two pieces of work where the conditions were substantially the same—the Lake survey before referred to, and our survey of some portions of New England. Both were executed with the strictest attention to accuracy; both had long stretches of shore line; the climatic conditions similar, if not more favorable to the Lake Survey. Gen. Comstock reports the cost of the topography of the Great Lakes as $151 per square mile; a former superintendent of the Coast and Geodetic Survey (C. P. Patterson) places the highest cost per square mile for the New England coast at $97.

Another point urged in favor of the traverse method is the number of checks it receives before being accepted. Capt. Boyce in the discussion of Mr. Josiah Pierce's lecture on the use of the plane table enumerates a long list practiced in the Ordnance Survey. Now all these checks take time, and add to the cost of this final result. Given a proportionate amount of time and money the work of the plane table can always be checked. From two commanding stations the accuracy of the survey of a large area can be determined with unequaled rapidity. It is a lack of check of some of the work done in this country which has thrown discredit on this method. An attempt to cover large areas at small cost, has resulted in the acceptance of all matter, good, bad, and indifferent, and from this mass of incongruity is evolved a map, fair in appearance and false in detail.

METHODS OF TOPOGRAPHICAL WORK ADOPTED BY THE U. S. GEOLOGICAL SURVEY.

The Geological Survey, whose methods and instruments are more akin to our own than those of any other bureau under the Government, commenced during the past decade numerous topographical surveys in various parts of our territory. Mr. Henry Gannett in Science, July 1887, outlines the methods pursued.

The scale for the published maps adopted for populous regions was 62500, or about one inch to the mile; for the Southern and Central

States, 125000; for the sparsely settled regions of the Rocky Mountain Plateau, 250,000; and the field sheets to be twice the scale of the published maps. They represent all natural features of drainage and relief in degree of detail proportional to scale. The relief is expressed by contours, and the interval, according to the horizontal scale and degree of relief of the country, ranges from 10 to 200 feet; the smallest contour interval accompanying the largest scale and *vice versa*.

The topographic work is in part prosecuted by plane table, using it by the method of intersections and in part by traverse methods. Both were used in Massachusetts. New Jersey was traversed with a compass and odometer, the relief being determined by the wye level; the District of Columbia by telemeter traverse; the Appalachian region mainly by compass and odometer, the elevations by barometer and vertical circle. In Missouri and Kansas, data were compiled from the General Land Office and the heights measured by barometer, making use of railroad profiles wherever practicable. The Dismal Swamp, Virginia, was traversed by plane table and odometer; the contour interval was 5 feet, determined by the wye level.

	Scale.	Cost per square mile.	
Massachusetts.	62500	$12·00	No$\triangle^{n}$
New Jersey.	62500	6·50	Some$\triangle^{n}$
District of Columbia.	62500	7·30	
Appalachian region.	125000	3·00	
Missouri and Kansas.	125000	·90	

From Mr. Gannett's "Survey and Map of Massachusetts," National Geographic Magazine, Vol. I, No. 1, I have abstracted the following:

For convenience the field work was done on a scale of 30000; the relief was expressed in contour lines traced at vertical intervals of 20 feet. The map represents all streams of magnitude sufficient to find place on the scale; and all bodies of water, as lakes, swamps, marshes, etc. It also contains all towns, cities, villages, post-offices—in short, all settlements of any magnitude—all railroads, and all roads with the exception of such as are merely private ways; all public canals, tunnels, bridges, ferries, and dams. There were excluded private roads, fences, various kinds of crops, and at first isolated houses; but subsequently, in response to the urgent wish of the Commissioners, the Survey consented to locate the houses upon the field maps. Forest areas are shown on the original sheets.

There were upward of 500 triangulation points, mostly determined by the Coast and Geodetic Survey, but in part by the Borden Survey and the Geological Survey.

Throughout most of the western part of the State the work was done entirely with the plane table, using the methods of intersections. The plane tabler, starting with three or more locations upon his

sheet, furnished by the triangulation, expanded over the sheet a graphic triangulation. This was done beforehand, before the sheet had an opportunity to become distorted by alternations of moisture and drying. This done, the plane tabler went on with his usual routine work, locating minor points and sketching the topography in contours.

Elevations were determined as the work progressed with the vertical circle of the alidade, and minor differences of elevation between points whose height was known were measured by the aneroid barometer.

The large plane table of the Coast and Geodetic Survey was first used, then the smaller form; finally the one designed by Mr. W. D. Johnson, of the Geological Survey, which is substantially a modification of the ball and socket movement, was adopted.

In the undulating, forest-covered regions of the southeastern part of the State, the roads and principal streams were traversed with theodolite and stadia; and from these lines the country lying between them was located and sketched.

The area surveyed by the method of intersections exclusively comprises 3 500 square miles, about three-fifths of the State. In this area 3 123 stations were occupied by the plane table, or slightly less than one to the square mile. Besides these, 17 846 points were located in this area by intersections, making a total of 20 969 locations within the area, or 6·2 horizontal locations per square mile. In the same area the heights of 34 893 points were measured, being 10 per square inch of the published map.

The area surveyed by the traverse method is 2 800 square miles. In this area 5 615 miles of traverse lines were run, being 2·2 linear inches per square inch. In running these lines 46 524 stations were made with the theodolite, being 8·3 per linear mile of traverse and 18·6 per square inch of map. The number of measurements of height was 92 561, being 37 to the square inch. The plane-table party consisted of one man and assistant, and was furnished with a horse and buggy. In the traverse work the party consisted of a traverse man and a rodman. No horse and buggy was furnished. The average output per working day of the plane tabler has been for the whole survey 3·1 square miles, and of the traverse man 2·8 square miles.

DETAILED TOPOGRAPHICAL SURVEY OF THE CITY OF ST. LOUIS, MO.

A large scale (1–2400) survey of St. Louis, Mo., has been in progress since 1889.

It is based on points derived from the transcontinental triangulation of the Coast and Geodetic Survey. Numerous bench marks were established and the average error of closure of level lines was 0·013 feet per mile. The party consists of 1 topographer, 1 recorder, 3 stadia men, and 1 utility man. A Buff & Burger transit is employed, reading horizontal angles to 10 seconds and vertical angles to 1 minute.

The stadias were 12 feet long and distances could be read by them to 458 metres.

Intermediate distances between bench marks were determined by vertical angles.

All traverse lines began and ended at a triangulation point, or other station on connecting lines. The contour planes were 3 feet apart. Number of elevations per acre, 3·65. Scale, 2400. Contour planes, 3 feet apart.

Cost of triangulation....	$1812·00
Cost of leveling.....	2762·00
Cost of topography.....	6060·00
Cost of office.....	6266·00

Average cost per square mile $724·50, or $1·13 per acre.

Central Park, Fairmount Park, and other localities were surveyed with the plane table by corporations and private individuals, but the processes employed do not present any peculiar features that I am aware of.

The purpose of this paper has been to note briefly the various methods employed in this country and to give a succinct description of several surveys, each one of which seemed typical of a class.

Our own topographical surveys illustrate the healthy growth of an organization in which the vital principles of accuracy, adaptability, and improvement are manifest.

The end to be attained has always been kept in view, and the purpose has always specified the means for its attainment. A rigid adherence to a high standard of accuracy where small errors would involve the peril of many lives or great wealth has been sturdily maintained against a constant and persistent pressure for more, if inferior, results.

Yet when the purpose has been the greatest amount of information in the shortest time, and preciseness a minor consideration, our methods have proved sufficiently elastic to adapt themselves to the needs of an army in a strange country.

During the war of the rebellion large areas were covered by Coast Survey officers attached to the various armies, and yet such was their skill that their sketches often misled many into supposing them to be finished instrumental surveys.

A story is told of a certain engineer officer who was deceived in this manner, and after locating his earthwork by means of a sketch growled vigorously because he could not also compute the amount of excavation by it. In all probability the sketch covered 4 square miles and was the result of half a day's work.

These military surveys are an example of our most rapid, and the cadastral surveys for harbor and city improvements specimens of our most painstaking and accurate work.

In nearly all the plane table was employed and has proved its efficiency.

In closing I would state that there are certain conclusions which force themselves on one in going over, even hastily, the subject of topographical surveys, and they are:

(1) The plane table in this country is the most suitable instrument for all classes of work.

(2) It is still susceptible of improvement.

(3) A new material for plane table sheets is urgently needed.

(4) Compilations from any source are to be distrusted and only accepted after careful verification.

(5) A thorough system of inspection and checks should prevail in all plane-table work. The method should not depend alone, as it sometimes does, on the unknown quantities of the topographer's skill and honesty. A good inspection would soon pick out the incompetent, compel the careless man to do more accurate work, and the skillful and conscientious topographer would be stimulated by having the difficulties and excellences of his labors appreciated.

TOPOGRAPHICAL METHODS OF THE U. S. COAST AND GEODETIC SURVEY.

[Presented by Assistant D. B. Wainwright.]

An exposition of the instrumental and personal processes necessary for a precise and intelligible representation of nature; especially those processes peculiar to the plane table, and which constitute its special power and opportunity, sets forth the chief method of topographical work used by the Coast and Geodetic Survey.

This paper is largely composed of extracts from Assistant E. Hergesheimer's treatise* on the plane table, re-arranged for this purpose and with additions which seemed necessary to bring out more clearly some points of field practice.

For a full description of the instruments and their adjustments, explanations of the three and two point problems, various tables and plates, the reader is referred to that treatise.

As our surveys are intended to serve not only as charts of our coast and harbors, but also for the many purposes of navigation, commerce, and military defense, the topographical details to be mapped are numerous and must be quite accurately determined. Two scales, the 10000 and 20000, have been found the most appropriate for the various classes of field work; 10000 from Maine to Delaware Bay on the Atlantic coast; also for the whole Pacific coast; and 20000 for the remainder of the Atlantic and Gulf coasts.

The details might be shown on smaller scales, but it has been proved from experience there would be nothing gained, either in economy or

*U. S. Coast and Geodetic report for 1880—Appendix No. 13.

rapidity, from their use, owing to the tax on the topographer on account of the more minute drawing involved.

As in all plane-table surveys it is important that sufficient points shall be determined from a measured base, at such distances from each other that, when plotted on the scale of the survey, they may be reached by the rule of the alidade over the intervening spaces, it will be presumed that this has been done, as is usually the case in the Coast and Geodetic Survey, and that the sheet to be used on the table has these points accurately plotted, so that they bear the same relation to one another as the corresponding points of nature.

Signals having been erected at each triangulation point and also on all other prominent hills within the area of the sheet, where they would be useful in providing additional control, the next proceeding will be to occupy one of the former points.

Care should be exercised in choosing the day for this portion of the work, as it is essential that the plotted points of the triangulation should be tested, and new ones determined from them in the most favorable weather.

The chief and controlling condition in working with the plane table, and without which no accurate work can be done, is that the table shall be *in position;* that is, that all lines joining points on the sheet shall coincide in direction with the corresponding lines of nature.

When the table is in position at any determined point, any object in view may be observed through the telescope, and the edge of the rule being kept sharply on the point occupied, a line drawn along its edge will be the direction of the object observed; but as this determines only one element, that of direction, it will be necessary to determine its distance from the point occupied either by measure or by intersection of this direction by a direction from some other fixed point, which will intersect the first direction at an angle when practicable, not less than 30° nor more than 150°; all intersections can be verified by a direction from a third point.

When a direction has been drawn from a station to any undetermined point that can be occupied, the position of the point may be determined by occupying it with the table, and putting the table in position by the line drawn to it, and *resecting* upon a signal whose corresponding point is plotted upon the sheet.

Before leaving the station, lines to all prominent objects, natural or artificial, within the scope of the station should be drawn. If the height of the station be important, this should be determined, both as a guide for the lines of equal elevation in the immediate vicinity, and as a point of reference for determination of heights from other stations.

This should conclude the work at this point, and the topographer now proceeds to occupy others until he is satisfied that enough positions have been accurately fixed over the whole sheet.

No definite number of positions, either in regard to number of square

inches of plane-table sheet, or square miles of the region to be surveyed, has been determined upon. The nature of the country has had more influence in fixing the most desirable number of controlling points to a given area than any other consideration. Where the country is open and the triangulation stations commanding it are well placed, a few additional stations may suffice.

Enough, however, should be furnished so that there will always be several within the reach of the ruler, and not too near the edge of the board, no matter what portion of the sheet is exposed upon it.

The number of plane-table or secondary points may be considered sufficient when they are grouped together near enough so that a new station may be determined from them at any place on the sheet where one may be necessary for obtaining details or checking traverse lines.

From the foregoing it will be seen that the triangulation stations control the main plane-table stations determined as secondary points of control, and these in turn control the ordinary plane-table stations from which the topographical details are obtained. All details of sufficient importance to justify their exact location should be determined by intersections or measured to from the instrument.

There is often occasion for a nice discrimination in using the plane table (involving time, labor, and the command of ground) between an excessive number of telemeter measurements, with comparatively little sketching, and the reverse.

The former, besides entailing a loss of time, tends to dull the skill of the topographer as an expert sketcher, in giving less opportunity for estimating distance, relative proportion, and the characteristic expression of topographical features.

The latter will result in producing a map deficient in accuracy at critical points.

The best method is to adapt the two processes to the scale and the character of the detail. When the scale is large or the cultural features numerous, the frequent use of telemeter measurements becomes a necessity to insure sufficient accuracy. On the other hand, when the scale is small and the region sparsely settled a liberal number of stations should be occupied so as to obtain views of a feature from more than one point, and the details sketched in by the eye aided with a small number of telemeter readings.

For filling in this skeleton with all the details that may be desired, the plane table is set up at any desired place where a good view of the surrounding features can be obtained. If this place has not been previously determined, it is now effected by means of the resection of lines from three known points (the three-point problem). Next, angular readings by means of the arc of the alidade are taken on objects whose altitude is known, and the height of the instrument above the datum plane thus found.

Since no topographical map can be complete without some systematic representation of the undulations and changes of slope of the surface of the ground—terrene—caused by the oscillations of the earth's crust, erosion, abrasion, or artificial works, various modes have been devised for such representation.

The two methods of surveying curves of equal elevation are known as the *regular* and the *irregular* methods.

The *regular methods* include—

(1) Surveying and leveling the skeleton and its traverses.

(2) Surveying and leveling the profile lines.

(3) Surveying and leveling the base of each level section.

(4) Surveying and leveling the parts of several level sections from one station.

(5) The division of the terrene into squares, triangles, or parallelograms.

The *irregular method* consists in determining the positions and heights of a number of characteristic points of the terrene, and in determining from these the traces of the curves.

This is the method generally used in surveys embracing such areas as the sheets of the Coast and Geodetic Survey on scales of 1–10000 and 1–20000.

The vertical intervals at which curves should be drawn must be determined by the object and necessities of each case, and, in a measure, by the gentleness or abruptness of the slope. As a rule, with such features as prevail on the New England coast of the United States, intervals of 20 feet are found to develop the form with sufficient detail on 1–10000 scale, but, for purposes of construction, intervals of 5 feet or even less are often found desirable on larger scales.

In abruptly mountainous and comparatively inaccessible regions, where sketching must be relied upon, 100-foot curves may suffice to develop all necessary features.

Having already drawn the ground plan of the locality, the alidade is used both as a level for the observation of objects the same height as the instrument, and for measuring angles of elevation and depression to such of the platted details, whose position at critical points of the contours would materially assist the topographer in tracing them.

No rule can be laid down as to the number of elevations that should in this manner be determined from each plane-table station or for a given area. It will depend on the skill of the topographer and the modeling of the terrene. The number will be adequate when he is confident of tracing by their aid the contours with an accuracy sufficient for the scale and the purposes of the survey.

It would indicate careless and slovenly work if the contours were found, on examination, to deviate frequently from their true position on the sheet more than half an interval for a slope of less than 5° in an open country. Where the slope is steeper or in wooded regions a

greater latitude is permissible; but even here in representing the crests of ridges, prominent hilltops, and valley floors this limit of half an interval should not be departed from for good work.

Each case will present some peculiarities which must be met, as they are presented, by the topographer's own resources; and as on the ordinary scales of topographical surveys a limit of minuteness of detail must be fixed, a sound management of work, established by experience, will find its strength resting upon a discrimination between important and trifling features, and a ready decision of what to omit as well as what to include. Labor may be spent in the development of small individual features which are comparatively lost on the scale of the work, while the features characteristic of the forms produced by oscillation, erosion, or abrasion, indicative of the forces producing the same and which give distinctive character to the terrene, may be lost sight of in the too careful attention to minute details.

Having completed the work at a given station, the topographer proceeds with his party and instruments to an adjoining locality, where he selects a new station from which he can gather the details of an area bordering upon the one last surveyed. In this manner, by successively occupying points over the whole expanse of the sheet, the skeleton map is filled in.

In a wooded country, where it is impossible to find open space with range sufficient to see enough points for determination of position by resection, it is necessary to run traverses along the roads with offsets to such lateral features as it may be practicable to reach without the expenditure of excessive labor and time in opening lines of sight. The levels, when necessary, are carried along the traverse lines by angulation with the vertical arc of the alidade, taking back and fore sights at the alternate stations.

For this purpose the standard table is used on main roads and wherever the details are important and numerous. For, with compass, the deflections of the traverse will be only approximate, and with a transit instrument the necessity arises for platting with protractor on a sketch, with less accuracy and facility than the table affords.

When, however, the traverse line is unimportant, and few features present themselves to be noted; an auxiliary plane table oriented by a declinatoire or a transit fitted with stadia wires may be employed. When this method is pursued with a second table the forward station, as given by the telemeter, is not occupied, but another is chosen in advance of it, and from which it can be seen, where the instrument is set up and oriented by the declinatoire. Sighting the alidade to what is now the back station, the distance is read and platted along the edge of the ruler, and the point so determined represents the one occupied by the table.

It is apparent that this method is more rapid than the regular one employed on main roads, but far less precise.

The regular method consists in starting the traverse line by occupying some point previously determined and sending the telemeter ahead to a place selected for its advantageous position, in reference either to the surrounding features or facility in obtaining a new section of the traverse. Having sighted to this point, read and platted the distance, short guide lines should be drawn along the edge of the ruler at both ends and numbered or lettered, so they may be identified from others of like character. The table is then moved to the forward station, approximately oriented, and the platted point carefully plumbed over the one on the ground.

The alidade is now placed on the table and put in position by bringing the edge of the ruler close up to the guide lines; then by revolving the table until the vertical wire bisects the rod or signal, left for that purpose at the last station, it is oriented.

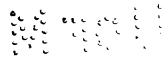
In running traverses, great care should be taken to sight as low as possible upon the fore and back signals, so as to avoid any error of deflection that might arise from inclination of the signal poles.

The stadia methods in plane-table surveys for measuring distance are either two horizontal fixed lines on glass, or webs in the diaphragm of the alidade telescope, which subtend variable lengths on a divided staff in proportion to distance; the staff having been experimentally divided on measured distances; or a micrometer eyepiece to the telescope, with two horizontal webs in the diaphragm, one of which is movable by a finely-cut screw, subtending a given length distinctly marked by two targets on a rod. The angle, as indicated by the rack and the divisions of the screw head, giving the distance from a table experimentally made on measured distances.

By these methods 400 metres may be measured within a probable error of 1 metre, which, on the usual scales of plane-table work, is inappreciable, and within the probable changes of the dimensions of the paper from its hygroscopic properties.

By the method of fixed lines in the diaphragm the angle remains constant and the chord variable, and by the micrometer method the chord remains constant and the angle variable.

For topographical reconnoissance a micrometer eyepiece in the telescope for distance measure is probably better than fixed lines in the diaphragm, because in the use of the former the chord on the staff or other object remains constant and can be made longer or shorter for greater or less distances, the variable angle being read with the micrometer. On a conspicuous tree or on the face of a prominent rock, especially when on the shore of a body of water, a vertical distance the length of the chord of the experimentally made micrometer-distance scale may be marked with whitewash, so that it may be used for the observation of distance from any point from which it may be visible.



A lone tree on a divide may for this purpose be valuable for a large arc of visibility.

Where it is necessary to make a topographical survey in advance of the determination of points by triangulation, a reconnoissance is first made for the location of a base line and selection of points to be determined with the plane table.

The base is then measured with sufficient accuracy for the purposes of the survey.

Signals having been erected at selected points, the extremes of the base are occupied with the table, and the points, as far as may be reached with good intersections, determined from them, and lines of direction drawn to all the points visible to serve as checks upon their determination from other points furnishing directions for good intersections. The survey then proceeds as usual.

It is well at the beginning of work to set off with the declinatoire at some determined point near the middle of the sheet the magnetic meridian, for the purpose of putting the table in approximate position at any station with the declinatoire.

Before finishing the field work it is important, when the sheet has no projection, to provide data for drawing a true north and south line. This is done by drawing from a point upon the sheet, when the table is in position, a line in the vertical plane through Polaris and the point occupied and recording the time of observation. The azimuth of the star at that time being known, a true north and south line can accordingly be set off.

If a small transit instrument is at hand and carefully adjusted for movement in vertical plane, an assistant with a lantern can be located where the vertical plane through Polaris and the point occupied intersects the ground at a distance of half a mile or more from the occupied station. When the assistant is in position a stake is there driven, the direction to which, from the point occupied, may be determined by daylight.

If, in the absence of a transit, the alidade has not vertical range sufficient to reach Polaris, an illuminated plumb line may be used for the alignment.

NOTES ON TOPOGRAPHICAL SURVEYS IN ITALY.

[Presented by Assistant D. B. Wainwright.]

The general topographical survey of Italy is carried on under the War Department, by the Military Geographical Institute.

The officers are selected from the general staff (état major), military engineers, artillery, cavalry, and infantry. A certain number of enlisted men are also employed.

The principal business of the Institute is the execution of all geodetic

and topographic works necessary to obtain the data for the construction of the topographic and chorographic maps of Italy, and those for military and other public services.

The triangulation is constantly two years in advance of the topography. The triangles are nearly equilateral.

The field sheets (scales 50000 and 25000) from the hands of the topographer are reduced and drawn on the scale of 75000 for the production of the final sheets, scale 100000.

The topographical and drawing divisions are both divided into four sections, based on skill and proficiency, with increase of pay according to term of service. The officers receive commutation of rations while in the field, and have their traveling expenses paid.

The field work is entirely done by means of the plane table. A field party consists of a captain of the general staff in charge, with from five to eight topographers (divided among lieutenants of infantry and general service men). Each topographer has two assistants, with stadia rods, by aid of which all horizontal measurements are made. The plane-table sheets, carefully prepared and mounted in advance, are inked in and practically finished in the field. All determined triangulation points are plotted, and altitudes marked also, in advance. These triangulation points are first checked, and the magnetic meridian is then laid down.

A very complete instrument is used with the plane table; the differences in elevation are computed at the station, the distances obtained by stadia measurements, and the contours drawn at 10 metres apart for the 50000 scale, and 5 metres apart for the 25000.

As much of the area now being done by the Institute has been covered by former topographical and cadastral surveys, several topographers may work on a single sheet.

Field minutes in the valley of the Po, vicinity of Florence, Rome, and Naples are drawn to the scale of 25000, and certain seaports at the scale of 10000.

A skilled topographer is expected to cover 50 to 60 square kilometres per month on the scale of 50000, and 20 kilometres per month on the scale of 25000.

Each hundredth metre curve is drawn heavy, and on the published map, scale 100000, the contours, 50 feet apart, alone are expressed.

The finishing of the original field minutes is done by both technical civil assistants and officers. These finished field minutes are converted into finished originals by more skillful draughtsmen, the line work transferred, the lettering, hachuring, and curves added.

The Director states, September 2, 1885, that the average cost per square mile (scale 25000) for field work (triangulation and topography) is $13.12. It must be remembered, however, in considering this small amount, that the salaries and wages paid in Italy are extremely small; and also a great deal of saving was effected by the use of former surveys.

Notes on topographical surveys in Europe.

Deville, in his treatise on horizontal photography applied to topographical surveying, states that this method was successfully pursued in mapping some portions of the mountains of Italy. He claims perfect success for the method in Canada, where 1000 square miles have been (up to 1889) surveyed in this manner; and says further, that its failure in other countries is due both to the use of too large scales, and to attempt to map areas having too little relief, as it is only adapted to mountainous regions.

I have been unable to obtain Paganini's treatise on the subject, which gives the results obtained in Italy.

These notes are abstracts from papers by Wheeler, Derrécagaix, and Deville.

NOTES ON SURVEYS OF ENGLAND AND FRANCE.

[Presented by Assistant W. C. Hodgkins.]

PREFATORY NOTE.

It should be borne in mind that, except in Great Britain and Ireland (where all official surveys are consolidated into one organization), there exists in every European country, so far as I can ascertain, a cadastral survey on a large scale, generally from 1–2500 to 1–4000, made for purposes of taxation, and thus furnishing, in advance of a topographical survey, detailed information in regard to all the subdivisions of the country. The fieldwork of the topographer is therefore comparatively simple. He has only to run out by traverse the roads and streams and to sketch the hill forms, all the minute and laborious work of plotting details being saved him.

GREAT BRITAIN.

The cadastral or ordnance survey of the United Kingdom is a wonderfully exact and elaborate work. In all its various processes it appears to aim at absolute certainty of results.

It is not necessary to detail here the preliminary processes of the survey, the astronomical and geodetic work, etc. Confining attention to the fieldwork of the topographical survey, it may be described as follows:

The triangulation having been completed (the sides of the tertiary triangles averaging 1½ miles in length) the rest of the detail work is done entirely by the chain.

The triangle sides are first gone over with the chain, all objects passed between the points being determined by offsets if necessary. The error of chaining must not exceed 2 links in 1000 or 1–500 of the length.

These chained lines furnish means to break the triangles up into still smaller ones by lines run between marked points on the first lines; and this process of subdivision is continued until all objects of detail are determined, including single or detached clumps of trees in the country, and in the city or town even the lamp-posts on the streets.

All of this work is plotted on a large scale, 1–500 for the cities and towns and 1–2500 for the rest of the country. It is afterward examined in the field and any accidental omissions are supplied. The elevations above mean tide, based upon standard level lines previously run, are placed upon the map, and in certain cases contours are run out.

The system followed is to stake out the course of the curve and then to run it out with compass and chain. In this way are run the 50, 100, 200, 300, etc., up to 1000, then every 250 feet up to 2500.

Intermediate forms are sketched on the ground after the curves run out have been plotted.

The published maps on smaller scales are obtained by photographic reduction, from the 1–2500 scale plotting.

In England the plane table does not seem to be used at all, but in the survey of India it is used to some extent for sketching details.

There does not seem to be much in the methods in vogue in the English surveys that would be of utility in rapid surveys of wild country or even in that which is well settled, unless very elaborate work were needed.

FRANCE.

The Dépôt de la Guerre was in its origin, in 1688, only a depot for documents collected in the archives of the War Department and relating particularly to history and military operations.

In 1761, the Depot of Charts and Plans was joined to it and enriched it with a valuable collection composed principally of topographic works, both printed and manuscript, executed by the engineers of the camps and armies during the reigns of Louis XIV and Louis XV. It was not until 1793, when the national convention intrusted to it the task of completing and retouching the plates of Cassini's great map that the Dépôt de la Guerre became an establishment for producing maps, and at that same time a school of topographical engraving was founded which has existed ever since.

For a long time the Dépôt de la Guerre held an independent position. In 1845, only, it was made part of the central administration and formed, up to 1871, a division of the War Department.

When the general staff of the minister was created the division of the dépôt was attached to the new organization.

Finally in 1887, the Dépôt de la Guerre was abolished and was replaced by the Geographic Service.

To the Geographic Service are intrusted all the operations of geodesy, of topography, and of cartography needed by the army in time of peace

as well as in time of war. It, further, investigates the improvements which may be possible in methods now in use.

The service is organized in five sections, as follows:

(1) Geodesy.
(2) Precise surveys.
(3) Topography.
(4) Cartography.
(5) Accounts.

The section of geodesy has charge of all work coming under that head and which need not be here enumerated.

The section of precise surveys executes large scale topographic work requiring mathematical exactness. This is a special duty directly connected with the construction of defensive military works. These surveys, moreover, constitute a basis for those which may some day be undertaken, should the constantly growing needs of the public service require the production of a new map.

The section of topography makes surveys upon the ground and prepares new maps for general use. It makes use of the geodetic operations to furnish a basis for its topographic network, to determine the relief of the ground, and to represent with exactness the details which ought to appear on the various projections. The thankless and difficult task of keeping the general staff map up to date by means of annual revisions also belongs to this section; also the surveys of Algeria and the preparation of foreign and colonial maps.

The official surveys of France are conducted under the War Department by the "Service Géographique de l'Armée."

These surveys are divided into two principal classes:

(*a*) Precise surveys.
(*b*) Topographic surveys.

Precise surveys.—This term in French usage seems to be applied to work on which much detail is shown and a certain precision is required, without necessarily implying that all the data given is exactly correct. At first the work done under this head was upon the scales of 1–2000 and 1–5000, and was restricted to the immediate vicinity of fortified places. As the extent of ground surveyed has increased, the scale has been diminished and the methods of work modified. At present most of this class of work is done on 1–10000, except in mountainous country, where 1–20000 is used.

Methods of work on 1–10000 scale.—The work on the ground consists of two parts:

The first part consists of the establishment of a general outline obtained by lines from triangulation points and by traverses along the side of polygons, following generally the roads and other means of communication. Along these roads connection is made at numerous

points with bench marks established by precise levels. In this way a network is obtained from 10 to 16 kilometres on a side and divided into small polygons. On the perimeter of these polygons are determined, by the aid of the tachymeter, the geographical positions and heights of a series of marked points, generally about 200 metres apart. This preliminary work is done with leveling compasses or with tachymeters which give angles to the nearest minute. The results of this first work are plotted upon the plane table sheet, together with a reduction to scale of the cadastral surveys.

The second part of the field work consists in revising the plotting of the detail reduced from the cadastral work and of drawing in the horizontal contours at intervals of 5 metres. Details are put in upon the plane table oriented by compass, using a special form of alidade with an attachment for rapid measurement of slopes. Pacing is resorted to for the measurement of distances when the details are not very important. In the plotting it is required that the traverses shall close within half a milimetre and the leveling within four-tenths of a metre. In the hill drawing on the plane-table sheet, traverses are largely used and points are added by radiation from stations. The curves are carefully drawn and records kept of all measures of vertical angles.

The above method is used in all sections not too much broken. It has even been employed in the Vosges and Jura Mountains, but had to be abandoned in high mountain regions. There, indeed, the reduction of the scale demanded the change. The steepness of the slopes made it useless to attempt the delineation of curves with sogreat a precision. Besides, as the work left the valleys, the running of traverses with the tachymeter became more laborious and lost exactness. It was then necessary to resort to more facile methods which still give a sufficient precision. This method has been followed since 1885 for surveys in Savoy and Dauphiné, the original sheets being on 1–20000.

Surveys on 1–20000.—As in surveys on 1–10000, the first step is the development of the general scheme, obtained by tachymetric traverses depending upon the stations of the triangulation. These traverses are almost always run in the bottoms of the valleys on account of the necessity of following routes which do not present too formidable slopes.

The circuits of traverses in the scheme increase in length on account of the scarcity of routes of communication and of the difficulty of working over them. The traverse scheme then proves insufficient, and it is necessary, in order to complete the preparation of the sheet, to introduce a new operation, consisting of the establishment of a graphical triangulation, starting from broken bases formed by parts of the traverses. This is accomplished by occupying the stations of the traverse and then determining by intersection all the objects which form natural or artificial signals.

The graphic triangulation is made with plane tables mounted on a ball and socket joint formed of a segment of a sphere, using large-

sized eclimetre rules. The slopes are taken during the traverse work by means of the tachymeter. All of this work is plotted upon the plane table sheet. The detail work is always done directly upon the plane table, oriented by compass ; but little traverse work is done. The positions and elevations are determined by the plane table with sufficient exactness.

The surveys of Algeria are based upon a geodetic triangulation connected with Spain on one hand and with Italy on the other.

The field work is done on 1–40000.

Heights refer to the mean level of the Mediterranean. Wherever cadastral surveys exist they are reduced to 1–40000 and transferred to the plane table sheets, upon which the triangulation points have already been plotted.

The field work is done chiefly with the compass provided with telescope and vertical arc. The barometer is also used for elevations. In ordinary country discrepancies of heights should not exceed 2 metres, in mountainous country, 4 metres.

The hill drawing is begun at the most elevated points and is carried downward. From 4 to 12 points in each square kilometre are determined in elevation.

Where the compass can not be used on account of local attraction the plane table is used.

South Algeria is surveyed on 1–100000 with the plane table oriented by compass, and with heights determined by aneroid barometer.

METHODS OF TOPOGRAPHICAL SURVEYS IN GERMANY, AUSTRIA, AND SWITZERLAND.

[Presented by Assistant J. A. Flemer.]

A—GERMANY.

The oldest military reconnaissances were merely sketched, the distances being obtained by the time it took a drilled infantryman to march over the required line without accoutrements or baggage. A Prussian soldier was supposed to cover 5.5 kilometres per hour in a level country. (The French assume that an infantryman will take 11 to 12 minutes to march over a distance of 1 kilometre, or will cover 5.2 kilometres per hour.)

With the aid of the plane table and the theodolite a gradual improvement has been established in this direction and the topographical maps of the Prussian general staff of the present time are ranked among the best productions of the topographic art.

Since 1871 the general staffs of Bavaria, Würtemberg and Baden have joined in the operations of the Prussian general staff. The surveys of the German Government can be grouped into four classes:

(1) Military Topographical Surveys.
(2) Cadastral Surveys (for taxation).
(3) Preliminary Surveys for Engineering Purposes.
(4) Scientific Geodetic Surveys.

Bavaria was the first of the southern German states to make a general topographic and a cadastral survey of the entire kingdom. This first survey was made in the first quarter of the present century and it was based upon a system of rectangular coördinates, invented and laid out by Soldner. This system of coördinates was subsequently extended over Würtemberg, Baden and Hessen.

Baden was the first of the German states to make a general topographical survey and to use *contours* for the delineation of the terrene (1825–1846). The new topographic map of Baden (1874) shows contours in 10 metres vertical interval; it is published in 170 sheets on a scale of 1–25000 and printed from copper plates in three colors. This map is based upon:

(1) The old topographical survey.
(2) Forestry and Cadastral maps.
(3) Resurveys.

The old maps were taken into the field and compared with the terrene; if small corrections only were needed, these were sketched in; larger corrections were made by special resurveys.

Military topography.—Under this heading we can distinguish two classes:

(1) Topographical surveys, made as such, and independently carried out.

(2) Topographical surveys based upon cadastral surveys.

The former have been chiefly practiced in Prussia, Saxony and Baden.

The latter (based upon cadastral surveys) are represented by the surveys of Bavaria and Würtemberg.

The general topographical maps ("General—Stabs—Karten") of all the German states show a remarkable uniformity in their general appearance in regard to general detail and accuracy. Germany has spent great sums of money, much skill and labor in the work of revision, and is continually improving the maps and bringing them up to date.

The process of a general topographical survey of a country passes through three stages:

(1) Triangulation.
(2) Actual topography.
(3) Cartography.

Triangulation.—Theodolite-polygons originated along the Rhine under French *regime*, and the effectiveness and accuracy of the trigonometric methods were soon generally recognized and now are used throughout.

(Hanoverian Triangulation, by Gauss; Triangulation of Lauenburg, by Schumacher; the Prussian, by Bessel and Baeyer; the Bavarian, by Soldner and Schwerd; the triangulation of Würtemberg, by Bohnenberger; the Hessian, by Eckhardt, etc.)

In Austria, Prussia, and Baden the triangulations were carried out by the general staffs.

The German primary triangulation has triangle sides from 10 to 100 miles in length. The base lines are measured with the highest accuracy attainable. The latitude and longitude of at least one point in each triangle have been determined by careful astronomical observations, and also the azimuth of at least one side of every primary triangle.

The network of primary triangulation is subdivided into triangles of the second, third, fourth, and fifth order. All of the points are well marked and described, and they form the initial stations for the topographer; from whence all other points are determined, with aid of the plane table; at least, such is the custom in Germany, Austria, and Switzerland.

The ordinary plane-table sheet in Germany (17 by 20 inches) contains from 20 to 40 triangulation points for the use of the topographer. During the work of the triangulation, both spirit and trigonometric level operations are carried on, and the elevations of all triangulation points are determined by these two methods, while the elevations of all subsequent points, to be used for the delineation of the terrene are made by alidade and plane table, or in wooded sections by barometric leveling.

The barometers, in recent years, have been greatly improved and they are excellent for this purpose, the mean error being comparatively small.

In Bavaria and Austria barometric leveling has become a favorite method for topographical delineations of the terrene.

In the preliminary governmental topographic surveys for engineering purposes, in Germany, it is considered too expensive to use the level, and only for the final location of railroads, canals, roads, etc., the relief and contours along the line are determined by spirit leveling and for all general or preliminary purposes the terrene is delineated by aid of barometric leveling (aneroids).

In the southern states of Germany, in Switzerland and in Austria, the "method of barometric measurements with corresponding observations" is employed almost throughout for all general topographical surveys, lines of spirit levels being run along main roads, railroads, canals and rivers.

The aneroids chiefly used for leveling purposes are: Vidi-Naudet's aneroid (made by Goldschmidt in Zürich) with microscopical reading, and J. H. Reitz's improved aneroid, made by Deutschlein in Hamburg (known as Reitz-Deutschlein's aneroid) which has also a microscope for

direct reading, and it is claimed that 0.001 millimetre can be read off with ease. (Zeitschr. f. Vermessungswesen, 1874.)

According to tests made by Prof. Koppe with Naudet's aneroid, the diameter of circular scale being 12 centimetres, and based upon 248 observations on points originally determined by precise leveling, the probable error proved to be 1.1 metres. The direct comparisons gave the following results:

114 errors were found to be from 0 to 1 metre.
70 errors were found to be from 1 metre to 2 metres.
47 errors were found to be from 2 metres to 3 metres.
14 errors were found to be from 3 metres to 4 metres.
3 errors were found to be from 4 metres to 5 metres.

The greatest error observed had been 4.4 metres. These tests were made under conditions similar to those which are met with in general traverse work.

Schoder (Hülfstabellen zu barometrischen Höhenmessungen) gives the probable error of Naudet's aneroid (12 centimetres), based upon forty seven observations, as 0.94 metre for differences of elevations lying within the range of 0 to 113 metres.

If we remember that the errors are not accumulative and adhere only to single points, not to be transmitted to subsequent points, this error may not be too great for general topographical purposes.

The elevation of every bench mark (determined by spirit level or vertical angle) which is redetermined by the aneroid will serve as the datum for all subsequent points, determined by aneroids, until the next bench mark is reached. In other words, all points which have been determined by aneroid readings will be referred to the last bench mark checked upon.

Rühlmann maintains that the horizontal distance between station and field barometer is not to exceed 37.5 kilometres.

Bauernfeind gives 60 to 75 kilometres as the limit in lowlands, and no ridge of hills should intervene between the corresponding barometer stations.

The station barometer is brought up to the advanced field barometer every night, and for this reason alone it will not often occur that distances over 30 to 40 kilometres will separate the barometers. Generally speaking, the cost of aneroid-leveling is low.

In 1873 two engineers with one assistant made a survey of 1,920 hectares for the Rhenish railroad, through a very broken country in fifty-nine days. The scale of survey was 1–10000, the levels were taken with aneroids. After the fieldwork had been completed, the elevations calculated and tabulated, the map was drawn, based upon Prussian cadastral maps, and the contours drawn in, in vertical intervals of 5 and 1 metres. The office work took twenty-eight days, including the location of the proposed railroad.

Methods of topographical surveys in Europe.

For final or special surveys for engineering purposes the scale is generally 1–2500 with curves in 1, 2, and, in very steep grades, 5 metre intervals. Whenever the character of ground requires it, subsurveys are made on scale 1–1000, or even 1–500.

Formerly every State had a separate datum plane or point of reference, to which the elevations of topographical surveys were referred. After the general topographical surveys, however, had been extended over several States it was found that the elevations and contours of adjoining States showed discrepancies, which in some instances were too great to be disregarded even for general purposes. It proved that none of the States had used the same plane for mean sea level, although all were referred to "the sea."

A number of lines of precise levels had demonstrated the fact that the mean level of the sea was different in different seaports (within several decimetres) and the central directory of the Prussian surveys decided to assume a datum plane which would satisfy the greatest number of the various datum planes which had been in vogue throughout the Empire, and after having decided upon such a plane of reference, to enforce the rule that in all topographical surveys the elevations and contours are to be referred to said plane.

Northern Germany had used the "mean sea level" at Amsterdam as datum plane, and it was found that the zero mark of the tide gauge at Amsterdam was in that plane, which satisfied the greatest number of the different datum planes heretofore used in different parts of Germany, by being very near the mean plane for all.

Subsequently this zero mark, termed "normal null," was taken as the initial point upon which all levels in Germany are to be referred and a point marked at the observatory at Berlin as being "37 metres above normal null" is the initial bench mark for all Prussian surveys. A net of precise levels extending from Memel to Basel in one direction, and from Cologne to Breslau in another direction, has been established by the German general staff, thus locating a large number of reference points throughout the Empire. The elevations and contours shown on the recently published topographical maps have been corrected with reference to "normal null." In Baden, for instance, the old data had to be reduced 2 metres to bring them down to the new datum plane ("normal null").

At the present time this plane of reference (normal null) is used throughout Germany, and the value of the uniformity thus established is considered as greatly outweighing the cost of the work.

There are three classes of leveling operations in Germany. Ranged in their order of accuracy they are:

(1) Spirit leveling.
(2) Trigonometric leveling.
(3) Barometric leveling.

For topographical surveys we find the plane table with distance-reading alidade and the tachymetric plane table chiefly in use. The reasons assigned therefor are:

(1) Its great effectiveness for the delineation of the terrene.

(2) Small damage to crops in gardens and fields.

(3) Saving of time by measuring distances to points only (and plotting their positions) which are cardinal points, omitting all secondary or auxiliary points.

(4) Little chance of omission of important features of the terrene or details.

In different parts of Germany we frequently find the plane table supplemented by theodolite and stadia (tachéomètre) measurements with compass and direct lineal measurements, with lineal measurements and offsets, etc.

Generally speaking, however, the plane table combined with spirit or even barometric leveling, is considered the most efficient method of making a well-developed topographical survey.

Traverse lines through forests are frequently run with tachymeter, theodolite, and compass, in combination with telemeter, steel tape, or even with Rud. Wittmann's measuring wheel. (Zeitschrift d. Oestr. Ing.-u. Arch.-Vereins, 1875.)

One well-trained topographical party ("general staff") will, on an average, survey about 0·3 to 0·5 square miles per day with the plane table, on 1–25 000 scale.

The tachymetric plane table method has gained many advocates in recent years, especially for the topographical surveys of Austria and northern Germany. One skilled topographer, with assistant, can determine 600 points with the tachymeter in a working day of ten hours.

Cadastral surveys.—These are based upon the measuring of a planimetric base line and lineal measurements along offsets, generally. In the southern states of Germany the plane table is extensively used for these surveys, while the northern states give preference to the polygonic methods using tachymeters, theodolites, compass, etc.

The cadastral maps of Bavaria are lithographed on 1–5 000 scale, those of Würtemberg on 1–2 500 scale; Duchy of Brunswick, 1–3 000 scale for general maps and 1–1 500 for towns and villages.

The city of Hanover has been surveyed and mapped in quite an elaborate manner:

Scale of general map of city	1–5 000
33 sheets showing the streets	1–1 250
13 sheets of the 13 wards of the city, into which the city had been subdivided for this survey	1–1 250
13 sheets of the same 13 sections	1–5 000
Maps of all city lots and improvements	1–125
Outlines of buildings of all improved city lots, including descriptions of building material and estimated value of improvements	1–125

Methods of topographical surveys in Europe.

The city of Berlin was surveyed on a scale of 1–250. The published plans are printed from copper plates on scale of 1–1 000. The plans are scratched into "gelatin paper," the scratches filled with graphite dust and transferred to a thin wax coating upon the copper plates. After having been engraved on copper these plans are transferred to stone (by Straube in Berlin) in order to get prints from these, avoiding the distortion caused by wetting the paper from copper prints. An extensive system of precise leveling was carried out upon which the new survey of Berlin has been based. In 1886 over 4 000 bench-marks had been established on iron bolts (inserted into walls and buildings) specially designed for this purpose.

The permissible error for level lines is given in condensed form for the new Berlin survey as follows:

2 millimetres, error for lengths up to 50 metres.
4 millimetres, error for lengths from 100 to 250 metres.
6 millimetres, error for lengths from 500 to 750 metres.
8 millimetres, error for lengths from 1 000 to 1 500 metres.
10 millimetres, error for lengths from 2 000 to 2 500 metres.
15 millimetres, error for lengths from 6 000 to 7 000 metres.
20 millimetres, error for lengths from 11 000 to 12 000 metres.

In the city survey of Hamburg the aneroid of Reitz-Deutschlein was used (in wooden case and with microscopical reading) and curves run with this instrument in a vertical interval of 1 metre. (With these instruments interpolations, within half an hour's time and within a range of difference in elevation up to 80 metres, have been made with a mean error of $\pm$ 0·4 metre.) (Zeitschrift für Vermessungswesen, 1873).

Photogrammetry has been practiced by the Germans for military purposes chiefly, although a special chair is maintained at the royal technical high school at Charlottenburg, near Berlin, for the study of this branch of topographical surveying. It is recommended for hilly, steep-cliffed regions and for the study of lateral changes in beaches and shore lines generally. The Germans also use a number of reflecting distance-measuring instruments in cases where it is difficult to employ rodmen. The following list comprises the most popular ones of this class of instruments:

The engymeter of Fallon (Austria).
Distance measurer of Adri & Son (Germany).
Distance measurer of Tavernier Gravet (France and Germany).
Distance measurer of Fortin (France and Germany).
Distance measurer of Ceribotani (Italy and Germany).

Ceribotani's distance measurer of 1 metre base gave for distances of:

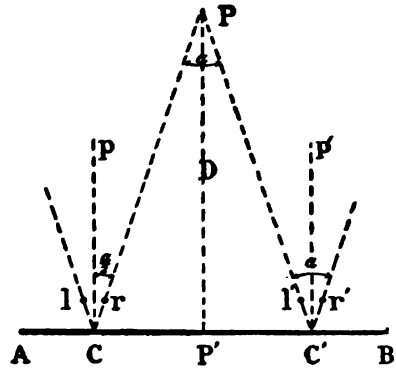
150 metres an error of 0·2 metres.
300 metres an error of 0·8 metres.
600 metres an error of 3·2 metres.
1 000 metres an error of 10·7 metres.
2 000 metres an error of 42·7 metres.
3 000 metres an error of 96·0 metres.

Oertel & Son, in Munich, have constructed a distance-measuring telescope which is highly recommended:

A B is a rule over which a telescope (with two vertical wires) can slide in either direction, the optical axis of the telescope always remaining at right angles to A B.

The distance D of point P from station A B is to be determined.

The telescope is clamped on the zero mark C of rule A B, and the whole instrument moved to the right or left until the right-hand wire *r* bisects P. The rule A B is now held in this position and the telescope moved towards B until the point P is bisected by the left-hand wire *l*.



The angle α is given for every instrument.

C P′ = P′ C′ can be read off or measured on AB.

$$\sphericalangle \text{P C P}' = 90^\circ - \frac{\alpha}{2}$$

$$tg\,\frac{\alpha}{2} = \frac{\text{C P}'}{\text{D}} = \frac{\text{C C}'}{2\,\text{D}}$$

$$\text{D} = \frac{\text{C C}'}{2\,tg\,\frac{\alpha}{2}}$$

B.—AUSTRIA.

The new special topographical (military) survey of Austria which was begun in 1869 in Tyrol, is published on a scale of 1–75000.

The field sheets were plotted on a scale of 1–25000 and the survey is chiefly based upon the cadastral survey of the Empire. In the mountainous regions, each working section (four of which make one special map sheet of 30 minutes length and 15 minutes width) contains on an average 1 600 points of elevation (bench marks), which number is reduced for the more level parts of the country, where one sheet contains

about 400 of such points. These points of elevation are based upon level-lines of precision, (13 800 kilometres of which had been run at the end of 1884, giving 2 417 primary bench marks) and upon data furnished by the military and cadastral triangulation. Each working section had on an average eight or nine elevations of precision or primary bench marks, upon which the number mentioned above (400 to 1 600) was based. These subsequent points were established, partly trigonometrically, partly barometrically with Naudet's aneroid. The contours are given for intervals of 100 metres, where the grade is over 10° and in 20 metre intervals for grades less than 10°.

Based upon this survey on field scale of 1–25000, the special topographical map of 715 sheets was published on 1–75000 scale. (The entire map would cover an area of 133 square metres.)

The published sheets are arranged so that the east and west margins are meridians in equidistant intervals of 30 minutes each.

The top and bottom margins are parallels in equidistant intervals of 15 minutes each. The projection used is the same as in Prussia, the polyëder projection. The total map extends from 42° to 51° 15′ latitude and from 27° to 44° 30′ longitude. The zones are counted from north to south (1 to 37) and the columns from west to east (I to XXXV). This survey was finished in April, 1885.

This work has been published by heliogravure.

The cadastral survey upon which this topographical survey was based had for its basis a triangulation and plane table survey, and it was made in three scales for different localities: 1–12500, 1–6250, and 1–3125.

With the aid of this cadastral survey and level data, obtained as mentioned above, and by combining the plane table with direct measurements the terrene was sketched in on the 1–25000 scale field sheets.

One topographical party (military) averaged 0·9 square mile per day on scale 1–25000 and 0·4 square mile on scale 1–12500. Goldschmidt's aneroid is extensively used for running out contours in Austria, the rodman carrying the aneroid, by means of which he adjusts his position, before holding his rod up on the critical points of the contour.

C.—SWITZERLAND.

The methods generally used for topographical surveys in this country have been alluded to in the preceding pages.

The original sheets of the topographic atlas of Switzerland for rolling country are on 1–25000 scale; for mountainous country, 1–50000 scale.

The general maps of the same regions are published on scales of 1–100000 and 1–500000, respectively.

The Dufour atlas, in twenty-five sheets, is published on 1–100000 scale; the same has been reduced to a wall map in four sheets of 1–250000 scale.

In the retrospection of the foregoing report I would respectfully suggest a consideration of the following:

(1) The polar method as originally devised by Lehmann and improved by combining the telemeter with the plane table (Reichenbach's telemeter, first described in Dingler's Polytechnic Journal of 1850 by G. Decher) has now almost been supplanted by the tachymetric method.

This method (tachéometric) was first employed by French engineers and has been in use since 1860. Tachéomètre (in Germany tachygraphometer or simply tachymeter) avoids both the reduction of telemeter reading to the horizon, and the calculation of the elevations, based on the vertical angle and reduced telemeter-reading (with aid of formula or tables), inasmuch as the tachymeter performs these calculations automatically. The use of the new tachymetric plane-table also dispenses with the use of dividers for plotting distances. The fact that this instrument has superseded the plane-table with distance-reading alidade throughout Europe would suggest a closer inspection and investigation of the merits of this instrument with a view of increasing the rapidity of topographical surveys.

(2) The marked improvements in the construction of aneroid barometers in recent years (invented by Vidi, 1847, and constructed by Bourdon in 1848; improved by Naudet; by Goldschmidt, in Zürich, 1859; by Reitz and Deutschlein in Hamburg; by Prof. Weilmann in Zürich, etc.) have justified their use in leveling operations made for topographical purposes.

The method of barometric determination of elevations for the plotting of the terrene by employing aneroids, has chiefly been perfected in Austria (in a measure also in the southern states of Germany and England) where Vidi-Naudet's aneroid is principally used. In Germany, Goldschmidt's (self-registering) and Reitz-Deutschlein's aneroids are preferred for topographical purposes. In Austria contours have been run out (on calm and cloudy days) by placing the rodman on a contour and noting the reading of the aneroid. The rodman then proceeds to follow the contour out, selecting the next characteristic change in its course, and moving up or down hill until the aneroid gives the same reading as at the first point. He then holds the telemetre in this new point of the contour until the observer at the plane-table has read the distance and waved him off, whereupon he selects the next point on the contour in the same manner, and so on.

If the aneroids are sufficiently trustworthy to give the elevations within a limit of error of one metre (Schoder, in his Hülfstabellen zu barometrischen Höhenmessungen, Stuttgart, 1874, has given the mean error for the elevations of 47 points lying within a vertical range of 113 metres as 0·94 metres) the trial of these instruments seems advisable for traverse work through wooded sections and also for rapid general topographical surveys.

NOTES ON EUROPEAN TOPOGRAPHIC MAPS, FROM THE REPORT BY GEN. DERRECAGAIX TO THE INTERNATIONAL GEOGRAPHICAL CONGRESS HELD AT PARIS IN 1889.

[Presented by Assistant W. C. Hodgkins.]

BELGIUM.

Independent Belgian surveys were not instituted till 1831. In that year, on January 26, the Dépôt de la Guerre was established. In 1878 its title was changed to that of Cartographic Institute.

The maps of Belgium are prepared on the three scales of 1–20000, 1–40000, and 1–160000. The maps on the last two scales are derived from the first.

At one time a map on 1–80000 was proposed and was actually begun. This would have harmonized with the maps of France and of Rhenish Prussia and Westphalia on the same scale. But the latter maps having been supplanted by the 1–100000 map of the German Empire, one of the reasons for the existence of an 80000th map of Belgium disappeared. Besides, the map on 1–40000 gave all principal details and that on 1–160000 was excellent for more general purposes. It was found that the 80000 would often show too much or not enough detail, and as from the military point of view it did not offer advantages proportional to its cost, it was decided to abandon it.

There is also a map on 1–10000, which is simply an enlargement of the surveys on 1–20000.

The field work on 1–20000 is based upon an old triangulation, revised and completed since 1831. The triangulation was completely finished in 1866, and comprises 4 182 triangles of the three orders, in an area of 29 455 square kilometres. It is connected with the work of the neighboring countries. The cadastral plans reduced to 1–20000 serve as a base for the preparation of the plane-table sheets.

The planimetry was verified and completed upon the ground.

The study of the relief was very complete, more so than in any country of Europe with the exception of some provinces of Holland.

The contour interval is one metre, except on the right bank of the Meuse, where it is five metres. Heights refer to mean low water of spring tides at Ostend.

DENMARK.

The general staff of the army has charge of the surveys. Decimal scales are used, but not the metric system.

Horizontal contours for the representation of relief were first used in Denmark.

The work began about 1830. The triangulation was finished in 1871. It is connected on the north with the Norwegian triangulation and on the south with the Prussian.

The geometric leveling of the first and second orders was begun in 1874 and, favored by the slight relief of the ground, has been carried on with especial care. The number of elevations determined varies from 150 to 260 per square mile.

The topographical surveys, begun in 1830, are invariably executed on 1–20000, by the aid of pantographic reductions of the land (or cadastral) surveys on 1–4000.

These reductions are fitted to a reduction of the geodetic triangulation; then completed and revised on the ground.

The topographer occupies each of the stations of the precise levels and determines by radiation the positions and elevations of enough points to insure the exact drawing of the curves, the vertical interval of which is 5 Danish feet (1·57 metres = 5·15 feet United States standard). Upon slopes above 14° the interval is 40 feet.

The work is published on 1–20000 in photolith. Size of sheets, 0·38 by 0·314 metres. It is also published on 1–40000 and 1–80000, these sheets being engraved on copper in excellent style.

The engraving is done with Porensen's "chalcograph," a kind of pantograph which has a finely pointed diamond upon the tracing point. The reduction is thus done directly upon the copper and is afterwards touched up by hand. The engraving is too fine for good effect.

HOLLAND.

The chief characteristic of the Dutch surveys seems to be the great minuteness with which all details are shown.

The relief is in general slight, and therefore single houses can be shown even on 1–200000.

The older surveys were made on 1–25000 and published on 1–50000.

Since 1874 a new survey of the rivers on 1–5000 has been in progress.

PORTUGAL.

Surveys are made on 1–50000 and 1–100000. Published sheets on 1–100000 and 1–500000.

The work is of rather low grade.

Curves are shown at intervals of 25 metres on the 100000 and of 100 metres on the 500000.

ROUMANIA.

The triangulation of Moldavia is connected with the Russian scheme in Bessarabia and with that executed by the Austrians in Wallachia in 1855–'56–'57, also with the Transylvanian triangulation.

The first topography done was in the Dobrudscha, which, being almost flat and nearly uninhabited, offered a favorable field for a first attempt.

This survey was finished in 1886 and the more difficult work in Moldavia was then taken up, and 80 sheets were done there in 1887 and

Notes on European Topographic Maps from a report by Gen. Derrécagaix.

1888. The force consisted of one major, 1 captain, and 32 lieutenants. The work was done on 1–50000 in the Dobrudscha and on 1–100000 in Moldavia. Relief is shown by contours.

The plane table is used, with a German pattern of telescopic alidade. The compass is also used.

The published charts are lithographs in colors, on 1–200000. Projected roads are shown by dotted lines. Telegraph lines are shown.

Few elevations are given; averaging one in 40 square kilometres.

RUSSIA.

A corps of military topographers was established in 1822 and completely organized in 1826. In 1866 the corps was re-organized, and consisted of 6 generals, 33 superior officers, 156 officers, 170 topographers, 236 topographers ranking as corporals, 42 students. The appropriation was $136 000.

In 1877 the section of military topography was again re-organized with a main office at St. Petersburg. In 1887 this service included 10 generals, 24 officers of the general staff, 154 officers, 223 topographers, and to supply vacancies, 12 officers of infantry, 42 assistant topographers, 2 civil employés, a total of 447. The law requires a force of not less than 367 persons.

The field work is done on 1–21000 in the settled districts and on 1–42000 in the northern provinces and on the great steppes of the east.

The compensation of the officers ranges from $4 240 for chiefs of sections to $1 020 for assistant topographers.

An academy or training school is connected with the service.

During the war between Russia and Turkey, the corps made surveys of the country traversed by the Russian army, and prepared a map on 1–126000. In three years, 180 topographers determined 51 astronomical stations, measured 6 base lines, completed a triangulation of 1 287 stations, surveyed 46 900 square miles and made a reconnaissance of 5 500 more. The bases were from 3 to 6 kilometres long, and were measured with wooden rods. The triangulation was connected with the Russian and Austrian systems.

In the settled districts the surveys were on 1–42000, elsewhere on 1–84000. Relief was represented by contours at intervals of 8 metres, 10 metres, and sometimes more. In this way the survey of the Balkans was done in less than three years. This work corresponds, on an average, to the survey of a strip of country 238 by 38 miles, each year. The cost was very great, but the results were also remarkable.

In maps of Russia the scales are based on the number of versts to the inch.

The inch and foot are the same as the English.

The sagene equals 7 feet = 2·133 metres and is used for heights.

The verst = 500 sagenes = 1066·78 metres = 3 500 feet.

The principal maps are:

(1) The chart on the scale of 10 versts to the inch (1–420000) of European Russia in 154 sheets, and

(2) The topographic map on the scale of 3 versts to the inch (1–126000) of European Russia in 972 sheets and 59 sheets for Poland. There is also a map of the province of Moscow on 1–84000 in 40 sheets, a chart of Turkey in Asia on 1–840000, a military map of Turkestan on 1–680000, and in general maps called provincial on 1–210000.

The triangulation has extended over a long series of years and is of varying degees of precision.

Precise levels were begun in 1873. They generally follow the railways. They appear to be largely dependent upon vertical angles.

Field work was at first done on 1–146000 and 1–105600. In 1844, the scale of 1–42000 was adopted and later still 1–21000 for cultivated territory. Relief was represented by hachures.

In 1870, when the greater part of the western provinces was already surveyed, the form of the work was changed. The use of colors was rejected and a greater number of bench marks being furnished the topographers, the terrene was ordered to be represented by contours with intervals of 2 sagenes = 14 feet.

The surveys are now going on in the northwestern provinces, where in the last season 34 topographers surveyed 3778 square versts on 1–21000 at a cost of 67478 roubles (1658 square miles for $53982, or $32·56 per square mile). Each topographer averaged 24 square versts (about 10½ square miles) per month.

Other special surveys were also made on the southwestern frontier. The average cost of a square verst in European Russia is stated by General Derrécagaix at 17 roubles ($13·60), which would make the average square mile cost $31.

Surveys in Asia have been made on various scales from 1–17000 to 1–84000.

The chart on 1–420000 was begun in 1840, is engraved on copper and is kept up to date. The relief is shown by hachures with vertical light. There is also a lithographic edition in four colors. Each sheet includes 3° 30′ in longitude and 1° 48′ in latitude. Brown is used for the hachures, green for the forests, horizontal blue lines for the marshes, black for all other features. The number of buildings in each town is given on the chart. The map on 1–120000 is also on copper and is printed in black. Occasional elevations are given.

SPAIN.

In Spain, there are two organizations which produce maps. In 1856 the "Comision Militar del Mapa" began a triangulation of the country. In 1865 two divisions were formed, one for geographic work and one for statistics. In 1870 these were united to form the Geographic and Statistical Institute, which is under the direction of the Minister

of Agriculture and Public Works. In addition there is the Dépôt de la Guerre, under the direction of the Minister of War and engaged entirely in cartography and military reconnaisances.

The Geographical and Statistical Institute, which was re-organized in 1877, takes charge of the geodesy, the regular topography, the precise levels, the cadastral surveys and records, the legal metric measures, and publications in relation to statistics and meteorology.

The Dépôt de la Guerre has its own map making and printing establishment for the ready production of military maps.

The triangulation of Spain is of a very excellent quality, and is connected with the French work on the north and the Algerian on the south.

The leveling was also done with much care. Precise geometric levels were begun in 1871 and were supplemented by levels of the second order and by a network of traverse lines about 600 metres apart.

Heights are referred to mean level of the sea at Alicante.

Field work is done on 1–25 000 and shows the boundaries of the communes, all streams, means of communication, inhabited places, and culture. In this country, there are cadastral surveys for only a small part of the territory, and the survey is consequently slow. To limit to some extent the amount of work, subdivisions of less than 25 acres are omitted. Contours are drawn in the field at vertical intervals of 10 metres. Published maps are lithographed on 1—50 000, in colors.

SWEDEN AND NORWAY.

The corps of geometrical surveyors formerly had charge of the preparation of geographical charts of the kingdom. Now it is employed only in the publication of the cadastral survey, on the scale of 1–4000.

Ordinary surveys and map making are made by the topographic section of the Swedish general staff. There is also attached to this section an economic and statistical survey of the soil.

The cadastral survey forms the basis of all the others. When it is defective, a survey is made to supply the omissions or to correct the errors.

In Norway, the Geographic Institute of Christiana in charge of a superior officer under the direction of the Secretary of War makes the surveys and publishes the maps.

The triangulation of the two countries has been finished and revised, but is sparse in the northern parts.

Determination of relief rests upon precise levels carried across the country from sea to sea, and furnishing from twenty to twenty-five determined points per square mile.

Surveys are made on three scales, 1–20000 for settled districts and important places, 1—50000 or 1–100000 for the northern regions and high mountains. The land surveys on 1–4000, which form the basis for

the twenty-thousandth work, are not published. The originals are kept in the archives of each province, and copies are deposited in the central office at Stockholm or Christiana.

The principal published maps are those on 1–100000 and on 1–200000. There are also geologic and other general and special maps. All show a great amount of detail, made necessary by the peculiar character of the country. Roads, rivers, and the borders of lakes and seas are colored by hand. Both vertical and horizontal hachures are used to express relief, the former in arable land, the latter in rocky places.

The map of Norway is lithographed in colors. Contours in brown, water and marsh in blue, glaciers in green, the rest in black.

The general map of the two countries on 1–200000 is both engraved and lithographed. It shows nearly as much detail as the one hundred thousandth.

Relief is represented by 34-metre contours.

CONCLUSIONS OF GENERAL DERRÉCAGAIX.

The study of large scale topographic charts has brought out various general results, which may be thus summed up:

In addition to cadastral and tactical maps three general types have been adopted—

(1) Reproductions of the notes of surveys on a large scale, varying from 1–20000 to 1–50000, except in England, where there is a real, leveled cadaster.

(2) A topographic map, most commonly on 1–100000, as in Italy, Switzerland, Germany, Portugal, Sweden and Norway, and Roumania.

(3) A chorographic map on 1–200000, as in Austria, Holland, France, and Sweden and Norway.

From these facts, and recent improvements in methods and instruments, General Derrécagaix deduces the following proposals:

(1) The general use of the metric system to express heights.

(2) Uniformity in conventional signs.

(3) The adoption of a common scale for topographic and chorographic maps, the one hundred thousandth and two hundred thousandth being the best.

(4) The publication of reproductions of large scale surveys.

PHOTOGRAMMETRY—SHORT HISTORICAL REVIEW OF FRENCH AND GERMAN SURVEYS.

[Presented by Assistant J. A. Flemer.]

Regarding a photograph as a geometrically true perspective, photogrammetry will be the art of reconstructing geometrical projections, upon a plane surface of the terrene given and represented in perspective views.

The theoretical, fundamental principles upon which such reconstruc-

tions are primarily based were already known to Lambert, who published a work on perspective as early as 1759.

The French savant, Beautemps-Beaupré, attempted the first practical application of these principles for the use of topography while on a scientific expedition in 1791–1793, when he made perspective drawings of coast regions, and later constructed topographical maps based on these drawings. A map of a part of Van Dieman's Land, and also of the island Santa Cruz, was obtained by him in this manner.

Although Beautemps-Beaupré frequently referred to the feasibility of constructing topographical maps based on this method, the same almost sank into oblivion until M. Laussedat, major in the French army, again took the subject up.

In 1851 he constructed a modified "camera clara," which was superceded in 1858 by the "camera obscura," with additional improvements by Regnault, for surveying purposes.

Laussedat made numerous experiments with Regnault's improved "camera obscura," partly on his own behalf and partly under the auspices of the French ministry of war. His experiments were continued by Javary from 1863–1870.

The first German record on this subject is probably the article published in Horn's Photographic Journal in April, 1863. This article is a description of Laussedat's experiments, as given by him in a meeting of the French Photographic Society, held January 9, 1863.

We find Meydenbaur's first publication on photogrammetry in the June number of the Photographic Journal for 1863 ("Photographische Mittheilungen"), in which he uses the term photometography, which was subsequently changed into photogrammetry.

Pujo and Fourcode published a joint essay in Les Mondes, 1865, on "Goniometrie Photographique."

In the March number of the "Photographische Mittheilungen" for 1866, we find an article by Vogel on the use of Johnson's photographic apparatus for making topographical surveys, in which he shows the construction of vertical and horizontal angles.

Ever since Meydenbaur first became interested in the method of photogrammetry he endeavored to interest private and governmental surveyors in the method.

Jordan and Hauck have also done much to popularize this method in Germany.

Since 1869, photogrammetry was treated both theoretically and practically in the Royal Building Academy (Kgl. Bau Academy) in Berlin, Prussia, in the lectures on geodesy and photography. Several years ago the new Royal Technical High School in Charlottenburg, near Berlin, was completed, and since then a special chair has been maintained there for the purpose of teaching photogrammetry theoretically and practically; at present Dr. Pietsch fills said chair.

The first attempt to make a more extended practical survey with the camera in France was made by Laussedat in 1861, when he mapped a portion of the city of Paris, which work was followed by the photographic survey of the town of Grenoble, under the direction of the French Ministry of War. The area covered by this survey was 0·4 square mile. The field work lasted sixty hours and the office work two months.

Javary's work in this direction closely followed Laussedat's.

In Germany, the first larger attempt was made in 1867, under the direction of the Royal Prussian Ministry of War and Commerce, consisting in a topographical survey of the town of Freiburg, and also an architectural survey of the dome in Freiburg. Field work lasted four days. The area covered about 0·04 square mile. The office work for the construction of the topographical map took three weeks. The drawing of the ground plan, one front and one side elevation of church, took eight days.

During the Franco-Prussian war, photography was called to aid by the German army, and a detachment for field photography was formed to obtain and plot a certain area about Strasburg with the aid of the camera.

This detachment (under direction of Dr. Doergens, now professor of geodesy in Berlin, Techn. High School) made a map, scale 1–2500 of the besieged front of the city. The data obtained by this survey, however, were not utilized, as the city capitulated a few days after the detachment had commenced its work. Some discrepancies were discovered in this survey, which were attributed to defects in the lens of the instrument used.

Jordan, a member of Rohlf's African expedition, 1873–1874, made a good photogrammetric survey of the Oasis Gassr Dachel, in the Libyan Desert. In 1874, Stolze used a Meydenbaur camera-theodolite to make a survey of the ruins of Persepolis and of the temple of Djamâht in Shiraz, Persia.

ASCERTAINING AND REPRESENTING UPON A PLANE SURFACE ANY PORTION OF THE SURFACE OF THE EARTH, BY MEANS OF A PHOTOGRAPHIC PROCESS KNOWN AS "PHOTOGRAMMETRY."

The idea of utilizing the image obtained with a "camera obscura" for a geometrically true representation of terrene or buildings, is probably as old as the camera itself, but the chances of the realization of the idea have become probable only with the improved methods and general progress made in photography during recent years.

Experiments in this direction were notably made, at an early date, in Italy and France; practical results, however, failed to materialize, swing partly to the uncertainty and slowness of the photographic process in general, and partly to the greatly increased efficiency of other surveying instruments and methods.

By mastering photography and combining it with geodetical instru-

Photogrammetry or Photographic surveying.

ments, the idea of photographical surveying has become a reality, and at this date must be regarded as a subservient factor in modern engineering no longer to be overlooked.

Mr. Meydenbaur, who spent many years in the study of this question, has perfected this idea, and also demonstrated the capabilities of photogrammetry by practical tests which proved the efficiency of this method of topographical surveying. Also in astronomical surveying, photography has led to excellent results.

Photogrammetry being comparatively a recent invention, has not yet attained its height of perfection, and it is susceptible of many improvements, still, notwithstanding the cumbersome nature of the camera-theodolite, compared with other surveying instruments, its use promises great results. Even at its present stage of imperfection, Mr. Meydenbaur has, with no other expedients or help than his camera and an instrument bearer, taken a photographical survey of a valley in a mountainous region in a few hours' time. After a lapse of several weeks he returned to his home, and there constructed a topographical map, based on the photographical data obtained in the field, and a subsequent comparison of his map with another obtained by plotting the results of a trigonometrical survey of the same region by another party, proved the correctness of his work.

Every survey is founded on the determination of horizontal and vertical angles, measured at the ends of a straight line (base line) of a known length. The camera produces an image of the terrene, which is to be surveyed, of the exact similitude as the observer beholds the terrene from the same point from which the picture was taken. In other words, the camera fixes the true perspective view of the terrene exactly as the observer's eye sees it in nature. Similarly as the observer selects certain characteristic points in nature and observes upon them, noting the result and constructing a map with the aid of the data thus obtained, he can discover and pick out the identical points on the photograph of the same terrene, and by graphical construction he will be able to draw a topographical map of the area covered by the camera's images.

The camera's image is produced by means of a biconvex lens, or rather a system of lenses, in a similar manner as we suppose a plane perspective view originates.

All visual rays emanating from an object A B to the eye *o*, form a reduced and inverted image, *a b*, on the retina. If a biconvex lens takes the place of the eye at *o*, the rays coming from A B will be refracted, and produce in the focus of *o*, a reduced inverted image *a b* of A B. Triangles *a o b* and A *o* B are similar ones. The focal distance *o m* is known or can be ascertained experimentally, for every camera, and the lengths of *a m* and *b m* are obtainable by direct measurements on the photograph. The angles *a o m* and *b o m* are also known or

given (likewise all angles which are included between the rays emanating from the point of view, and the given direction, *o m*, from the same point, can be measured on the photograph). The observation or determination of these (horizontal or vertical) angles becomes also necessary for the orientation of the camera-theodolite, which orientation is conditioned by the position of the optical axis of the instrument.

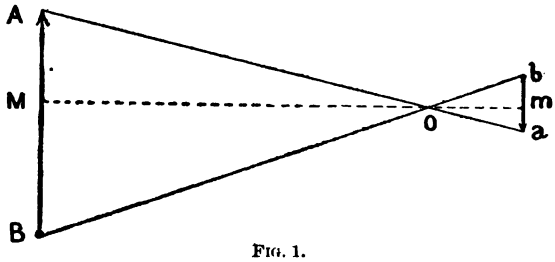


FIG. 1.

Whenever the deviation of the optical axis from a ray to any object represented in the image is given or known, the angles subtended by the optical axis and the lines to all the other points in the picture are given, both as horizontal and vertical angles, and in this fact rests the great superiority and importance of the photographic apparatus.

To transform the photographic camera into a photogrammetric camera, it was necessary to add several appliances, as the optical axis had to be made adjustable into a horizontal position for every station, the instrument had to be revolvable about a vertical axis in a horizontal plane to cover the entire horizon from one station, the optical axis was to be vertical to plane of image, etc.

The camera proper also had to receive some modifications, the chief additions being a set of cross wires. The horizontal and vertical planes became fixed on the photographs of this camera in such a manner that every picture taken with the instrument, after the same had been leveled up, showed two cross lines, which, with the optical axis (or with the vertical line to plane of image in their intersection) fixed the horizontal and vertical planes for every view. Originally this was obtained by the insertion of two very thin platina wires (crossing each other at right angles in the optical axis of camera) close to the sensitive plate, their positions becoming transmitted simultaneously with the picture to the plate by the action of the rays of light. In all instruments of more recent construction, however, the glass-plate supporter bears four small notches, which are printed upon the sensitive plate and photograph, and after the print has been dried these notch points are connected by straight lines drawn across the picture. By using sensitized films or paper instead of dry plates, a thin glass plate, inserted in the plane of image, can be provided with a system of equidistant and parallel lines (parallel to horizon and vertical plane,) which, becoming transmitted to the sensitive surface, simultaneously with the picture, will greatly facilitate measurements subsequently to be made on the photograph.

Photogrammetry or Photographic surveying.

The focal distance of this camera is made constant and it is determined for every instrument both by experiment and calculation, after having focused the apparatus with the greatest precision in regard to a sharp and well-defined reflected picture of some distant object on the ground-glass plate.

It is a well-known fact that the ordinary photographic double lens does not draw mathematically true images of the object represented, as every photograph appears more or less distorted on its edges, the minimum of distortion being in the central part of the picture. By shutting out the external rays (at a sacrifice of intensity of illumination) and by using well-curved lenses (spheroidal lenses) it has become feasible to obtain pictures which are practically correct, at least within certain limits (Mr. Meydenbaur maintains that they are true images if the angle subtended by the external rays does not exceed 110°), for all topographical purposes.

The external rays are excluded by means of a diaphragm A B inserted between the two lenses, which has a small circular perforation in its center (in the optical axis of the instrument). Annexed figure shows the combination of diaphragm and lenses.

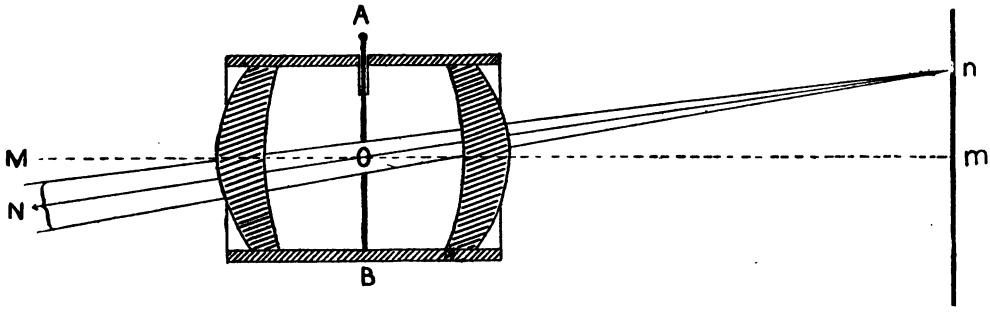


FIG. 2.

For an assumed focal distance of 200 millimetres, let the diameter of perforation at O be adopted as 10 millimetres.

Rays proceeding from a point N in nature produce the image *n* on the image plate. Owing to the perforation at O, only such rays emanating from N, which form a cone around the central ray N O *n*, with a base of 10 millimetres diameter at O, and the apex in *n* will be permitted to reach *n*.

If we designate the *principal focal distance* by f, and the focal distance of the lenses by *a* and *b* respectively, there exists the following relation between them:

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

$$b = \frac{af}{a - f}$$

Adopting for f the value of 200 millimetres, assumed above, and substituting for a different values lying between 10 and 700 millimetres, we find the following corresponding values for b:

	m.		m.
$a =$	10	$b =$	0·2041
	20		0·2036
	40		0·2010
	100		0·2004
	200		0·2002
	300		0·2001
	400		0·2001
	700		0·2000

From this tabulation we will perceive that if we have a fixed principal focal distance, say of 200 millimetres, the plane of image will intersect the cones of rays (which pierce the aperture in diaphragm) which emanate from some of the points viewed upon in a *circle* (or in an ellipse) instead of being intersected in a point (the apex of cone). This circle of diffused light increases in size with the decreasing distance of the object viewed upon (the image falling beyond the image plate) through the camera, as the instrument was focused on a distant object, and the focal distance is maintained unchanged for all operations, viewing objects near or far.

The diameter x of this circle (or ellipse) can be ascertained from the following relation:

$$x : O = f : a$$

$$x = \frac{f \times O}{a}$$

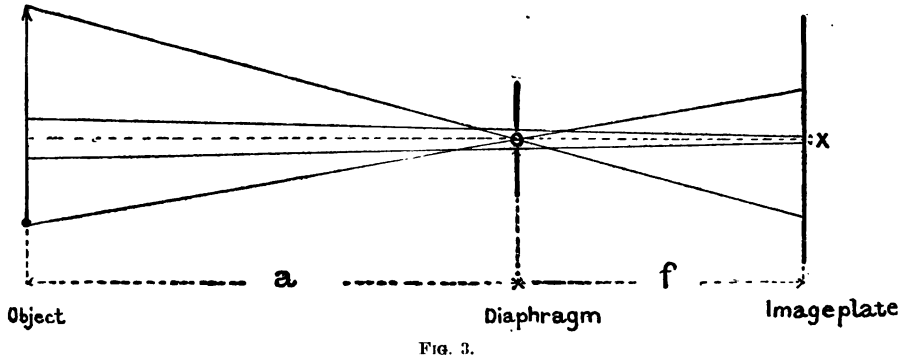


FIG. 3.

If O = diameter of aperture in diaphragm, assuming this aperture again to be 10 millimetres in diameter, and assuming the same values for f and a as shown in above table, we will find the corresponding values for x as follows:

	m.		mm.
f = 200 millimetres and $a =$	10	$x =$	0·2
	20		0·1
	40		0·05
	100		0·02
	200		0·01
	300		0·006
	400		0·005
	700		0·003

Photogrammetry or Photographic surveying.

This table shows that the diameter of the circle is very small for an aperture O of 10 millimetres, and as it has been found that a perforation of the diaphragm of only 3 to 4 millimetres in diameter gives good results for topographical purposes, the above tabulated values will become greatly reduced in practical work.

Practical tests have also established the fact that a sufficient distinctness of image is obtained at the small distance of 10 metres, as the human eye can readily locate the true center of a circle (produced by a cone of diffused light) of 0·2 millimetres in diameter, and the camera will, even at this extreme limit, give results of sufficient ac-

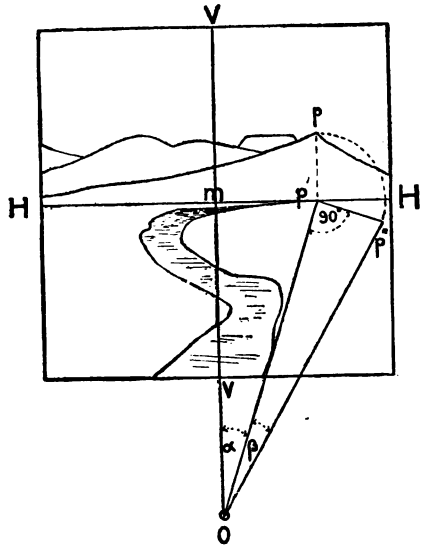


FIG. 4.

curacy. In fact, the focusing of the camera within a limit of 0·1 millimetre is extremely doubtful, being more readily obtained in the imagination of the operator than in reality. From the foregoing it will appear, however, that there can not be any objection raised against the preservation of a constant focal distance, and the operator will only have to level up the camera in the field to have it ready for work from that station.

The focal distance of a camera-theodolite is the fundamental value upon which the determinations of all angles, obtained by means of that camera, are based, and it is evident that a correct determination of this value (constant focal distance) will not only save much work, but will also avoid a number of sources of error.

Above figure (4) represents a photogrammetric picture,

H H=Horizontal thread
V V=Vertical thread

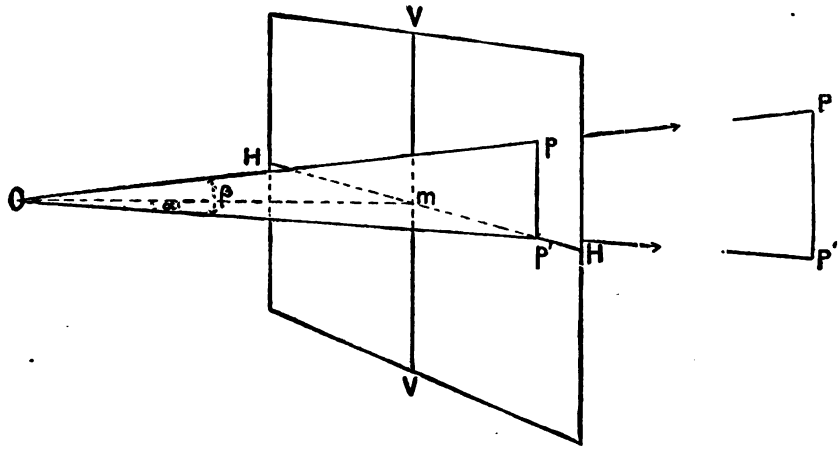


FIG. 4a.

The optical axis will be perpendicular to the plane of image in the point m (Fig 4ª). We want to find the angle α subtended by the line of vision O P (to P) and the vertical plane O V m V (Fig. 4ª), also angle β subtended by line of vision O P and plane of horizon O H m H (elevation).

By projecting the point p upon the horizon H H in the picture, we obtain a point p'; knowing O m=constant focal distance, and m p' (found by direct measurement on the picture) we can find the azimuth α and the hypotenuse O p' (Fig. 4) of the triangle O m p'. By measuring p p' we find the angle of elevation in the triangle O p' p.

These results are all obtained graphically, as indicated in Fig. 4, and subsequently utilized graphically in the construction of maps, employing similar methods as employed in the use of the plane table, the practical execution being far more simple than this deduction would permit it to appear.

The entire method of photogrammetry reposing on graphical measurements, the smallest length, measurable with eye and scale, will give the limit of correctness. According to Mr. Meydenbaur this limit is 0.1 millimetre.

The focal distance can be determined with great precision, even graphically, by a method which will also show the true position of the vertical thread in the picture and by repeating this operation the probable error may be reduced to 0.01 millimetre. The camera being mounted movable in horizontal plane, we can, by a series of exposures, obtain pictures covering the entire horizon. The number of exposures necessary for this performance depends upon the field commanded by the objective. Meydenbaur's instrument could sweep the horizon in six pictures, leaving a margin of 5 millimetres width common to two

adjoining plates. All objects within such a common margin can be identified on two plates, and, by using a magnifying glass, points common to two adjoining pictures can be located and marked upon the plates which are equidistant from the vertical thread. Whenever such distances from the vertical line (representing vertical thread) do not correspond with each other, the vertical line on the picture must be shifted until they "tally." After having located corresponding points on all the pictures, covering the horizon (say, six pictures) we will have twelve determinations for the position of the vertical line. If the camera is at all fit for use, the greatest difference in these twelve positions must not exceed 0.1 millimetre. The distance between two of these *corrected* vertical lines will give the length of the picture=2*l*. For a sixfold exposure, sweeping the entire horizon, we will have the relation:

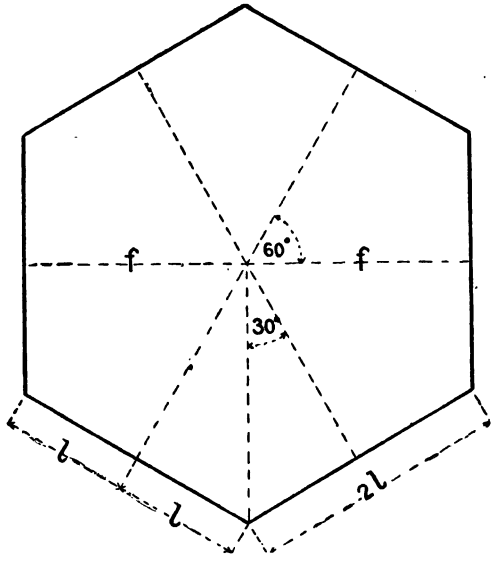


FIG. 5.

$$f = \frac{l}{tg\ 30^{\circ}};\ l = \text{mean value for length of picture.}$$

This is the most satisfactory determination for the focal distance of instrument, other methods being less reliable or more complicated.

When dry plates are used, it will become necessary to make an allowance for the changes which the image suffers during the process of being transferred to paper. With the exercising of care on part of the printer these changes will nearly be of a uniform character, manifesting themselves chiefly in the contraction of the paper while drying. The edges of the plate supports being printed on the edge of the picture,

and the distance of these supports being invariable on the instrument, we find in this circumstance the means for correcting the focal distance in accord with the contraction of the paper.

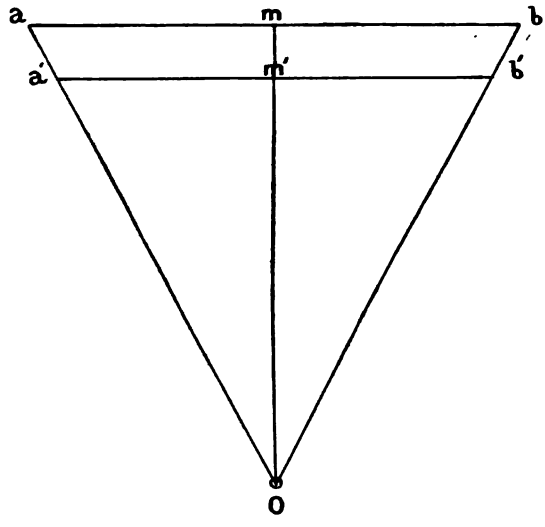


FIG. 6.—*a b*=original length of picture between plate supports in camera. *a' b'*=length of picture after having been transferred to paper and dried. *m* O=focal distance of camera.

By laying down the triangle *a b* O and placing the length of printed paper *a' b'* parallel to *a b*, and moving it from *a b* until *a'* falls upon *a* O and *b'* upon *b* O (*a' b'* being still / to *a b*), we find point *m'*, and can measure length of O *m'*= focal distance for contracted picture.

In order to distribute the weight of the camera-theodolite as nearly as possible upon the three leveling screws of the instrument, and thus facilitate its setting up and hauling, the optical center necessarily falls outside of the vertical axis of the camera. During a circular movement of the camera plate (surveying the horizon) the optical center will describe a circle of about 0·20 centimetres in diameter for ordinary instruments. In other words, the station point and optical center of pictures will not coincide with each other. The optical centers of the six pictures covering the horizon are, in reality, situated on the circumference of a circle of 0·2 centimetres diameter in the form of a regular hexagon.

For a scale of 1–1000 for the survey, the diameter of this circle will be only 0·0002 metres long, about the size of a fine needle puncture. For all topographical purposes, therefore, we can assume the optical centers to fall into one point—the station point.

The maps are constructed from photogrammetric pictures in the same manner as the plane table is used, and the operations may be described as follows:

Photogrammetry or Pphotographic surveying.

ORIENTATION OF THE PICTURES.

The simplest case would be that a base line had been measured, and pictures of the terrene had been taken from both end stations of this line. While occupying one end of the line, the other must be marked by some plain signal, which will be readily seen on a picture. In the pictures taken from the Stations (I and II) this signal should appear on plate I as a heavy short line, showing two flags (Fig. 7). The horizontal

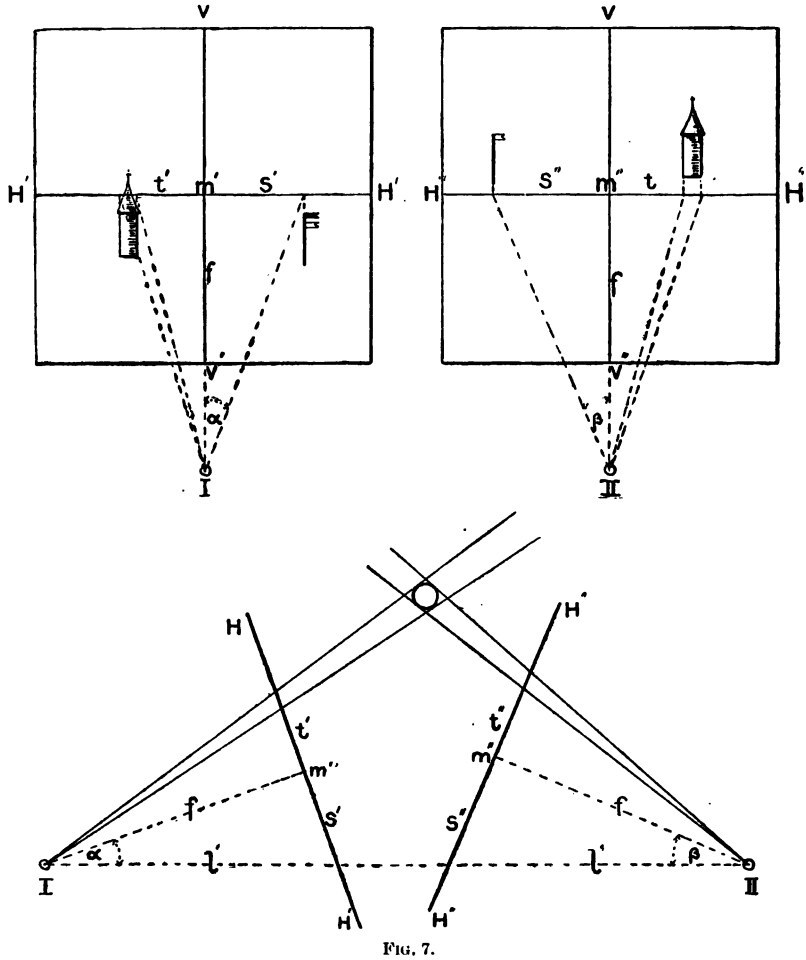


Fig. 7.

angle subtended by optical axis of instrument and the base line, during each exposure for the pictures, can readily be obtained graphically, as indicated in figure and described in preceding chapters. The size of these angles is entirely arbitrary and it is only necessary that the signal may appear at least on one of the pictures, even if the entire horizon is not covered by the exposures.

After having plotted the base line I–II (preceding figure) in reduced scale, the angles α and β are plotted with reference to the pictures to which they belong, and on these directions of the optical axis the known focal distance f is laid off from points I and II and the vertical lines (horizons H′ H′ and H″ H″) drawn through their ends. All the other pictures (having no special signal for orientation) are oriented as soon as the first one of the six has been oriented, as above, owing to the division of the horizon into six pictures, and herein rests the main advantage of the hexagonal division.

The entire orientation of the pictures is accomplished in a very short time, inasmuch as the triangles are all rectangular ones with known sides (f, *t* and *s*). The known focal distance f is laid off from *m* downward along v *m* v in the pictures, and after projecting the points of images upon the horizon we find *s* and *t*.

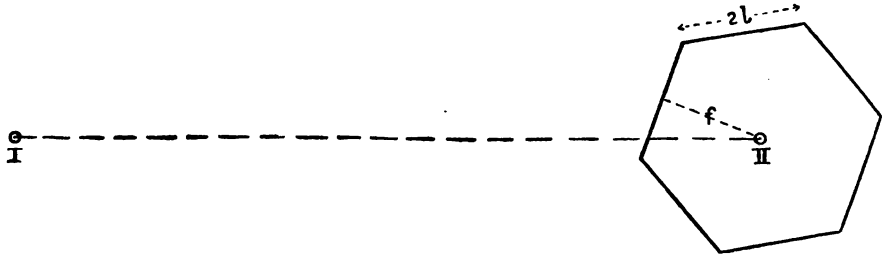


FIG. 8.

After the horizons have been located as shown above, the horizontal projection of any point, common to two plates, is found by intersecting. Thus the circular tower, indicated on the pictures taken from the Stations I and II is located. The distances *t* of the two sides of the tower from the vertical thread are plotted from *m′* and *m″* upon the horizons H′ and H″ respectively, new lines (rayons) are drawn from the end stations of base line I–II through these points, which lines intersect each other in a quadrangle, the inscribed circle of which locates the horizontal projection of the tower. The photogrammetric plotting is altogether very much like the plotting on the plane table, and, generally speaking, photogrammetry has the same advantages and disadvantages adherent to the plane table, except that the duration of the field work is reduced to a minimum.

In case the base line, or the line from which the observations are made, is not situated in the area to be surveyed, the orientation of the pictures can only be made with reference to a point or signal not situated on the base line, the position of which, in reference to the base line, however, must be known or determined. For this and similar purposes, Mr. Meydenbaur's instrument is convertible into a plane table by removing the camera and clamping a sheet of paper upon the camera supporter table, after which, lines of direction to the distant "object of

orientation" can be taken from both ends of the base line with the aid of a small alidade. By combining a compass with the camera additional advantages may be obtained.

After the horizontal projection p' of any point p has been constructed, the relative height P P′ of this object above the horizon of the instrument or picture can be readily found, as follows (Figs. 4 and 4ª):

O p and O p' found from horizontal projections, $p\ p'$ measured directly on surface of pictures.

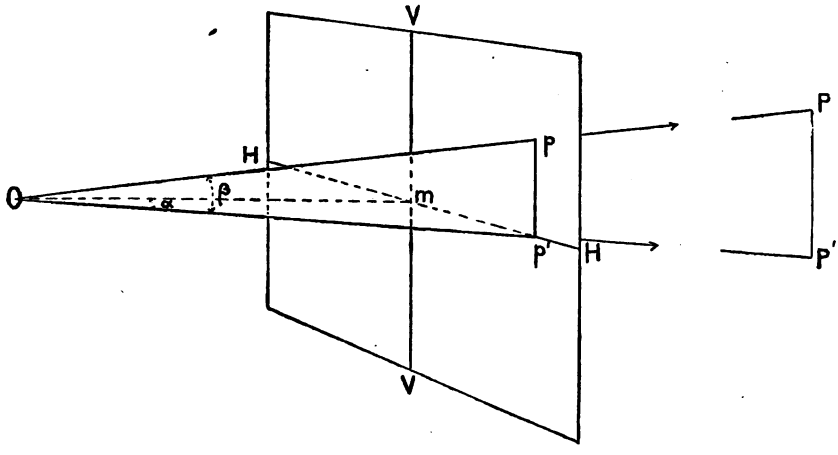


FIG. 4*a*.

We have the relation:

$$P\,P' : p\,p' = O\,P' : O\,p'$$

$$P\,P' = \frac{O\,P'\,p\,p'}{O\,p'} \text{ (with reference to the scale of the map).}$$

Measurements on the pictures are preferably made with a small ivory scale divided into millimetres. After some practice, the eye can estimate 0·1 millimetre very closely.

If a difficulty appears in finding or locating identical points on pairs of pictures, photogrammetry can not be employed. Still, with the erection of a few signals this evil may be remedied also. Owing to the fact that every point must be shown at least on two pictures in order to locate the same on the horizontal projection, an error of identity of a point in question is very improbable, insomuch as the twofold determination of the elevation of any doubtful point will give a good check; both elevations determined from two plates must give the same result if the point has not been mistaken for another.

After a sufficient number of elevations have been plotted upon the map it will be an easy matter to draw the contours by interpolation, which operation will be greatly facilitated by studying the pictures

taken of the terrene, from their different stations, just as one might take a map out into the field to sketch in some doubtful detail.

The scope and productiveness of the photogrammetric method greatly exceed the bounds which formerly surrounded the field operations of lower geodesy, as the following remarks may show:

A scientific exploring party may have sent home a number of photogrammetric pictures of their route of travel with the necessary data for orienting the pictures, and also sent the elevations of their horizons, H H, determined by aneroid barometers in this case. A distant mountain range may appear on two or more views, visible only in outline, owing to the great distance. It is possible to construct a system of contours which will represent the range with a considerable degree of accuracy.

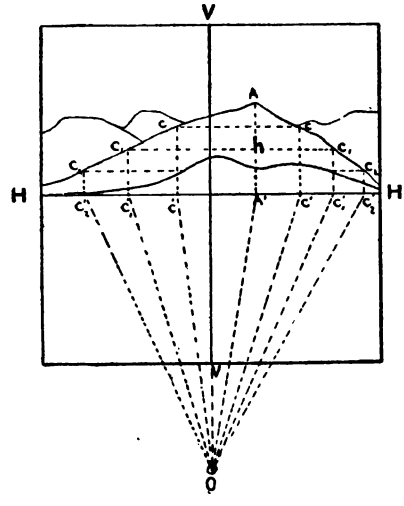


FIG. 9.

For this purpose we locate the horizontal projection A′ of the summit A, if it can be readily identified on several pictures, then ascertain the elevation *h* of A above horizon H H, which height we divide into a number of horizontal strata (with reference to the elevation of A above H H in the different pictures) in such a manner that the corresponding dividing planes are on the same level. Above figure represents one of the pictures thus divided into strata, the lines O C, O C_2 represent the tangential lines drawn from focal center O to the contours, as indicated by the dividing of planes of strata. These tangents are, it is true, not in the same plane as their corresponding dividing planes, but owing to the great distance of A from O this will cause an error too small to affect the map.

Adjoining figure represents the result of this operation after having drawn tangential lines from three stations, I, II, III (from the latter only the tangents to lower contour line drawn), and it is evident that

this method surpasses any other which an exploring expedition may have at command to determine the scope and elevation of terrene lying at a distance. The circumstance that the result obtained can be worked out at home, without the presence of any member of the scientific corps of explorers being necessary, seems to be another point in favor of the photogrammetric method. Military reconnaissance in times of war

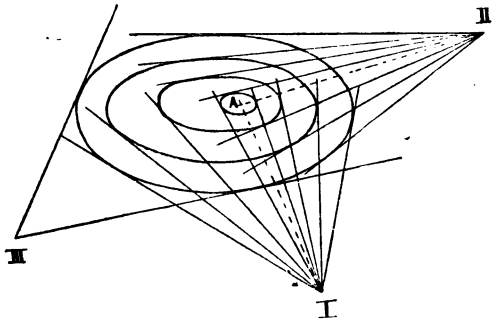


FIG. 10.

(secret surveys), preliminary surveys for engineering purposes in uninhabited, mountainous countries, etc., will find great help in photogrammetry, particularly when combined with the plane table, alidade, and barometer.

REPORT OF COMMITTEE ON METHODS OF BALLOON SURVEYING.

[Presented by Assistant D. B. Wainwright.]

Your committee begs leave to submit the following report on that portion of Assistant Bache's paper relating to topographical surveying by photography from a captive balloon, which was read to the Conference at its second session.

Your committee believes, from a short study of the subject, that it is perfectly practicable to have a balloon made as described by Assistant Bache, and to suspend from it a camera in the manner he represents, which will be sufficiently free from oscillation to obtain an accurate picture of the field of view.

Also, it seems to us feasible to hold the balloon in position,* or nearly so, over a given point by a set of four guys; and it is undoubtedly practicable to control the moment of exposure by an electrical device such as he indicates, connected with the shutter of the camera. Moreover, a traverse line laid out on level ground and marked in the manner given by Assistant Bache would serve as a means to correct any

* The height suggested by Assistant Bache is from 250 to 300 feet.

distortion of films or prints due to chemical processes, and any distortion due to perspective of lines lying in the same horizontal plane as the traverse line. But it is our opinion that the plan proposed is open to two serious objections which militate against its practical use—

(1) The amount of time consumed in mapping by this means a given area, owing to the small surface obtained by one operation or picture; the difficulty in moving forward the guys through bushes and trees or past buildings, and in preparing a new traverse line.

(2) All objects not lying in the same horizontal plane as the traverse line would appear on the picture out of place according to scale; thus an object on a hill 50 feet high and distant horizontally 150 feet from a point directly under the camera would measure, according to scale, over 175 feet from the same point;* and so for all objects above or below the plane of the traverse line a special reduction of each, according to height, would have to be made, necessarily involving a large amount of work and proving a fertile source of error.

It is not to be inferred from the criticism of the present plan that your committee holds an unfavorable opinion of all photography as applied to surveying. It believes a reasonably accurate map, of small scale, could be made of a flat or gently rolling country from a balloon at the height of several thousand feet, if only a balloon were susceptible of management at that height. It also believes that the question of mapping mountainous regions by means of cameras directed horizontally is worthy of discussion and investigation.

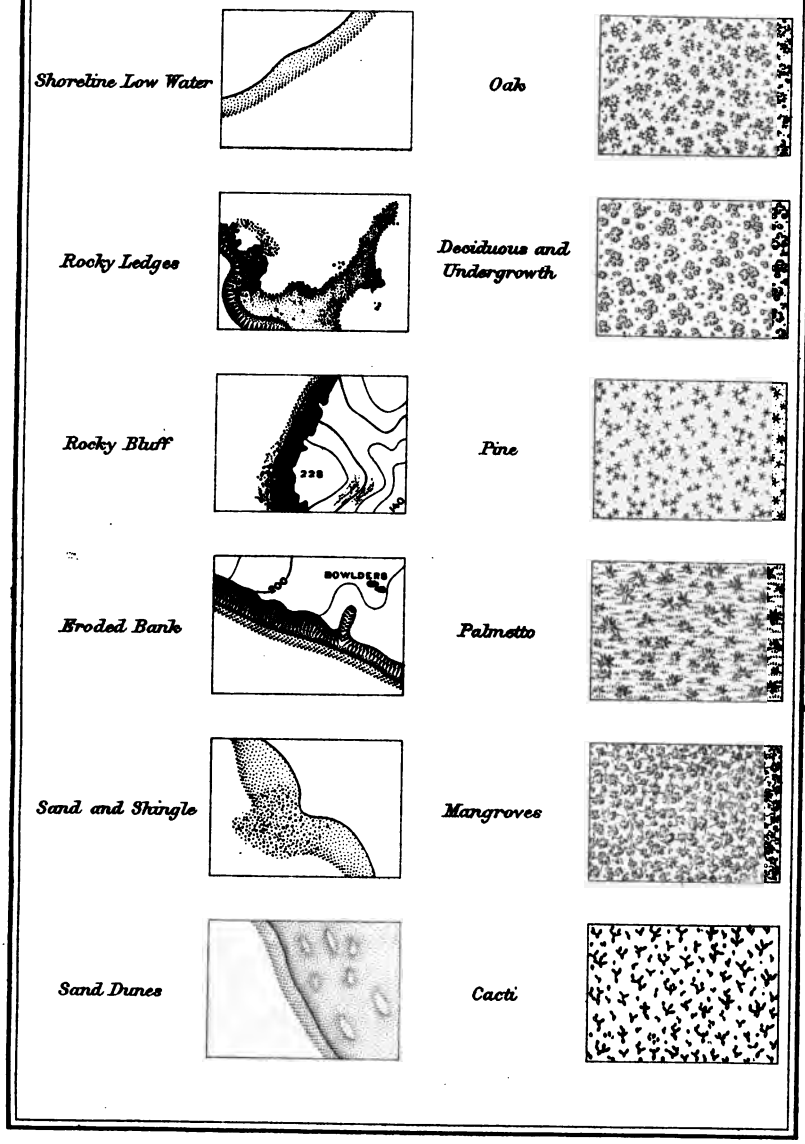
In conclusion, this committee would state that there appear to be serious doubts as to the applicability of the proposed method to the conditions practically existing in Coast Survey work; and though not feeling warranted in recommending any outlay in making the experiment, it acknowledges that if a sufficiently large area to afford a thorough test were surveyed, data would be furnished of much interest and probable value for a comparison in rapidity, accuracy, and expense between this method and those ordinarily used.

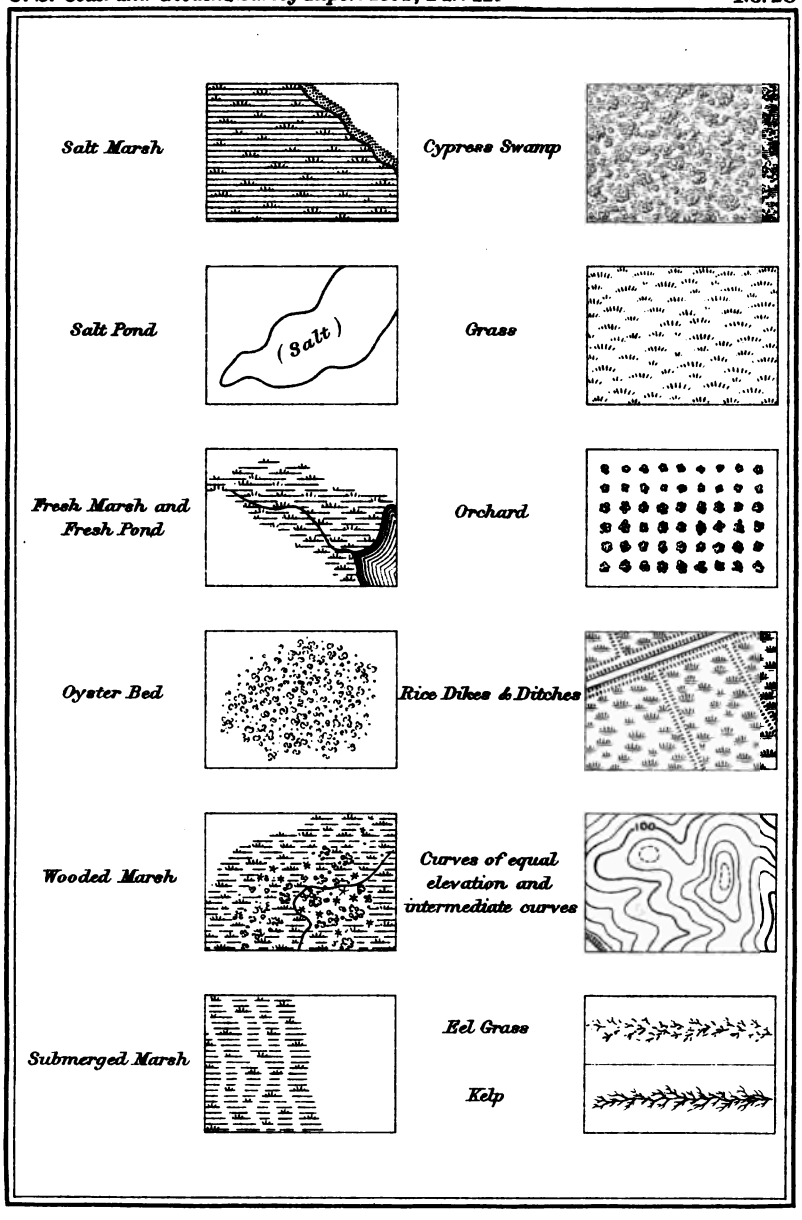
SUPPLEMENT J.

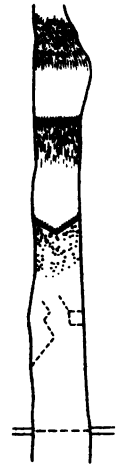
CONVENTIONAL SIGNS FOR FIELD SHEETS.

See page 576 for an abstract of the report of the committee appointed to secure still greater uniformity than heretofore in the use of conventional signs on the original charts of the Survey.

* Balloon supposed to be 300 feet high.


Shoreline Low Water
Rocky Ledges
Rocky Bluff
228
Eroded Bank
BOWLDERS
Sand and Shingle
Sand Dunes
Oak
Deciduous and Undergrowth
Pine
Palmetto
Mangroves
Cacti


Salt Marsh
Cypress Swamp
Salt Pond
(Salt)
Grass
Fresh Marsh and Fresh Pond
Orchard
Oyster Bed
Rice Dikes & Ditches
Wooded Marsh
Curves of equal elevation and intermediate curves
100
Submerged Marsh
Eel Grass
Kelp



Topographical Station

Triangulation Point

Dwelling House

Barn

Shed and Pen

Ruins

Windmill

Church

Cemetery

Fence

Public Road

Road fenced on one side

Telegraph Road

Railroad (each track)

Railroad (large Scale)

Road not fenced

Path or Trail

Stone Wall

Hedge

Embankment

Canal and Lock

Known Altitude ..... 420 ft.

Approx " ..... (approx) 420 ft.

Lighthouse (rays red)

Light-ship (" ")

Buoys (Can, Nun, Spar and Bell)

Red and Green

Black

Horizontal Stripes

Perpendicular Stripes

Whistling

Lighted

Mooring

Beacon (Lighted, rays red)

Spindle or Stake

Anchorage

Wreck

Rock awash

Sunken Rock +

SUPPLEMENT K.

LETTER FROM MR. HENRY GANNETT, CHIEF TOPOGRAPHER OF THE U. S. GEOLOGICAL SURVEY, DESCRIBING THE METHODS EMPLOYED ON THAT WORK.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY, GEOGRAPHIC BRANCH,
Washington, D. C., February 19, 1892.

MY DEAR SIR: At a meeting of officers of the Coast and Geodetic Survey last Tuesday, to which myself with others connected with the U. S. Geological Survey were invited, a question was asked by Mr. Ogden the substance of which, as I recollect it, was as follows: "Can you, as a result of your experience in topographic surveying, suggest any improvements on the methods the Coast and Geodetic Survey is now pursuing whereby its work may be more rapidly or economically carried on?"

At the moment I did not feel prepared to answer this question, but, upon consideration, it appears to me that a condensed statement of the organization and methods in use upon the Geological Survey may serve to develop the points of difference between the practice of the two organizations, from which the officers of the Coast and Geodetic Survey may select such features as, from their experience, seem desirable and fitted to the conditions under which their work is prosecuted.

Primarily, it is understood throughout the Geological Survey that the work is carried on for the sole purpose of making maps upon certain predetermined scales, and all the operations of the Survey are subordinated to this end. The primary triangulation is carried on merely for the purpose of controlling these maps, and the maximum allowable error in the work is limited only to that permissible upon the maps. Such being the case, the primary triangulation is comparatively cheap, from ten to twenty stations being occupied per month. A single occupation of a triangulation station is generally sufficient, and twelve to sixteen pointings upon each other station are made. Artificial signals are used throughout in the work. Such rapid progress is not, however, inconsistent with considerable accuracy in the results. For example, the triangulation in Kansas, executed in 1890, with an 8-inch theolodite reading by micrometer to two seconds, showed an average error of closure of 1–95, in one hundred and twenty triangles.

By the primary triangulation, three points are located immediately on or adjacent to each atlas sheet, such sheet comprising upon the scale 1–62500, 250 square miles, and upon the scale of 1–125000, 1 000 square miles. These sheets are projected, the primary points are plotted upon them, and all work from that point on is relegated to the

plane table. With this instrument all points capable of being located by triangulation are so located. For this purpose, a score or more of points are occupied upon each plane-table sheet, their positions having been determined prior to occupation whenever possible. Signals are used upon all points to be occupied. Points located, but not occupied, are not, as a rule, marked by signals. Such points consist of hilltops and other relief features, houses, churches, and other features of culture, points in the shore line, and any other points in the hydrography of the region which are susceptible of being so located. In other words, location by triangulation is carried on as far as is economic. This method of location serves two purposes. First, to aid in the location of the sketching, and, secondly, to locate in correct position the traverse lines. All this work is done by the Johnson plane table and with a telescopic alidade of considerable power.

Traversing, by which location is effected by direction and distance measurement, is carried on to a large extent. All roads are traversed, since it is the cheapest method of obtaining their alignment, and in unsettled parts of the country it is found necessary to run many traverses where no roads exist in order to supply the requisite control for the sketching. In the eastern parts of the country, roads average from 1 to 2 linear miles to every square mile of country, involving an enormous amount of traversing merely to obtain the roads. This traversing of roads serves also for the location of countless points in addition to those located by triangulation, forming a network closely covering the country. Traversing is done with the simplest possible plane table, which is oriented by compass. Directions are measured with a ruler having raised sights. Distances are measured by counting the revolutions of a wheel directly or by some form of odometer. Large numbers of minor points are cut in from the traverse lines. The traverses are fitted to the triangulation executed with the larger plane tables.

Datum points for heights are obtained by the use of the wye level. Secondary heights are measured by the vertical arc of the alidade, and elevations along traverses are in the main measured by aneroid closely checked by instrumental determinations, and to some extent by instrumental profiles.

The Geological Survey makes a clear distinction between instrumental determinations of position, which is characterized as the control of a map, and the sketching, which is recognized as artistic work. The sketching is done upon a skeleton map, which contains all the control, and it is done by the best sketchers available. The selection of stations for sketching is done with considerable care, regard being had to obtaining the best positions for seeing the country in its proper relations. Upon the scale 1–62500 sketching is rarely attempted at a distance greater than a mile and then only when it seems impracticable to obtain nearer views; as a rule, the sketching is done at much

shorter distances. The matter of generalization has received much attention, the fact being fully recognized that all maps must be in a greater or less degree generalized from nature. In connection with this as an immediate adjunct, the study of structural geology in its influence upon topographic forms has become a part of the education of the topographer.

The organization of the parties is simplified as far as is consistent with efficiency. A party engaged in primary triangulation consists ordinarily of the head of the party, a helper, and a man to build signals. A party engaged in plane-table triangulation consists of the plane-tabler and a helper. A horse and buggy is provided for carrying them about. A traverse party consists of a traverse man, with the necessary horse and vehicle, and the traversing is generally done by low-salaried men, since it does not require a high degree of skill. No rules regarding office hours obtain in the field, but men are expected to work all day.

The list of features represented upon the maps embraces all natural features of magnitude sufficient to be represented upon the scale, and all artificial features which are of public, as distinguished from private importance. Thus, there are represented boundaries of civil divisions, cities, townships, counties and States; houses, railroads, roads, streets, canals, bridges, fords, light-houses, etc. The outlines of wooded areas are mapped. There are not mapped fences, cultivated lands, or any other features which relate to the individual, rather than to the community.

The plane table triangulation of an atlas sheet, including some 250 square miles, occupies from one to two weeks in putting up signals and measuring angles, according to the extent to which this work can be carried. The traversing of such an area ordinarily requires about fifty days' work of one man, since a man traverses, on an average, about 10 linear miles per working day. The sketching of such an area requires from one to two months, according to the intricacy of the work, and the readiness and the facility of the sketcher. On an average, a party, consisting of its head, who does the triangulation and sketching, and one traverse man, with a helper, will survey entirely two atlas sheets per season.

As a matter of interest, I append to this a table showing for the Northeastern Division of Topography the area surveyed during the last season, the number of points located by plane-table triangulation, the number of miles that were traversed, and other derived data.

STATISTICS OF CONTROL, NORTHEASTERN DIVISION, U. S. GEOLOGICAL SURVEY.

[Scale 1-62500; contour interval, 20 feet.]

Area surveyed (square miles)	3 150
Triangulation stations	650
Number of square inches per station	47
Points located by triangulation	3 330
Total triangulation stations and located points	3 980
Number of above locations per square inch	1·3
Number miles traversed	4 460
Inches traversed per square inch	1·4
Number traverse stations	29 150
Traverse stations per square inch	9·3
Total locations per square inch	10·6
Traverse stations per linear mile	6·5
Heights measured with vertical circle	5 700
Heights measured by aneroid	23 886
Total measured heights	29 586
Heights per square inch	9.4

These locations are regarded as sensibly accurate upon paper, as indeed they must be, as otherwise the work would come to a standstill. The imperfections of the maps are to be looked for in the sketching, where they may be due to insufficient control, to inexpressiveness of the sketching, or to both causes combined.

I inclose with this a tracing, showing the amount and the distribution of the control upon a sheet surveyed in West Virginia during the past season, which will further illustrate this matter. (See illustration No. 31.)

Thanking you and the other gentlemen composing your commission for your courtesy in inviting us to join you in your deliberations, I remain,

Sincerely, yours,

HENRY GANNETT.
Chief Topographer, U. S. Geological Survey.

Prof. HENRY L. WHITING,
U. S. Coast and Geodetic Survey, Washington, D. C.

COMMENTS BY ASSISTANT H. G. OGDEN ON THE PRECEDING LETTER.

[Submitted February 24, 1892.]

The letter from Mr. Gannett, Chief Topographer of the U. S. Geological Survey, to the Chairman of this Conference, offers us an opportunity of comparing the methods employed by the U. S. Geological Survey in making topographic surveys with those employed by the Coast and Geodetic Survey.

Before instituting this comparison, however, I desire to say a word on the question I propounded to our associates of the Geological Survey

WEST VIRGINIA BUCKHANNON SHEET No. 31

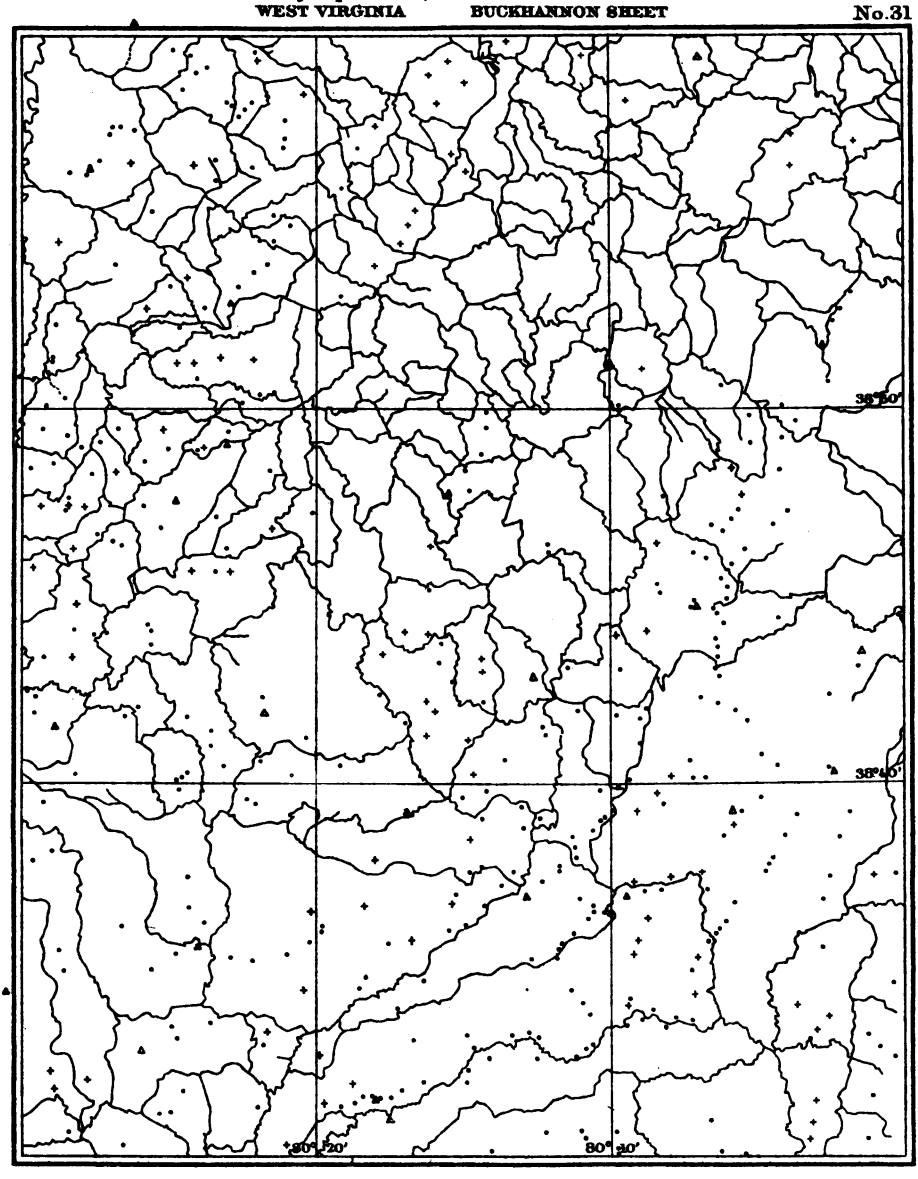


Diagram showing distribution of control work

Statute Miles

5 0 5 10

Main and Secondary stations ▲ Intersections from traverse +

Intersections from stations • Traversed Roads or Trails

Comparison of methods of making topographical surveys in the U. S. Geological Survey and in the U. S. Coast and Geodetic Survey.

when they joined us in conference a few days since. The subject I had in my mind at the time was similar to that stated by Mr. Gannett, but differed in so much that, I asked if the gentlemen present would state to us what part of the methods in use by them in topographical surveying could be applied advantageously to the work of the Coast and Geodetic Survey. While this has not been specifically answered, Mr. Gannett has, with great kindness, given us a statement of the methods used, and leaves to us to make the application to our own work. Mr. Gannett's statement refers entirely to the eastern half of the continent; it does not include the regions of the West, which, topographically, are very different, and are surveyed by a different method. As I have been informed by Mr. A. H. Thompson, the plane table alone is used in California, even in running such traverse lines as are found necessary through wooded areas.

The method described in Mr. Gannett's letter involves several operations, and covers the ground several times before the survey is plotted. It will be observed that a triangulation with computed sides is first spread over the area, furnishing a sufficient number of points to permit the use of the plane table in interpolating intermediate stations. The ground is then covered by a plane table triangulation in which elevations, so far as practicable, are determined by means of the vertical arc. Up to this point we may say that the method is identical with that employed on the Coast and Geodetic Survey. But in supplying the details of shore line, roads, elevations, etc., that are still required to complete the survey, the methods employed are radically different.

On the Geological Survey, the system of traverse lines forms the basis for the determination of all these details, these traverse lines being tied on to the stations of the triangulation and the plane table. Sometimes, in running the traverse lines, elevations are also determined, either by angulation or by the barometer, but I judge from the description given us that in many instances, after the traverse lines have been obtained, the ground is again covered with the barometer survey. But whichever way this traverse work may have been conducted, it seems plain that after it has all been completed and adjusted into place, the elevations being given also, the sheets, or sections of sheets, are taken in the field by still another party or officer of the party, and the hill work sketched in by the data on the sheet of traverses; this officer checking the previous work, as may be required, by the barometer, and running such additional traverse lines as he may find necessary, where the work furnished him has not cut up the country sufficiently close to permit the sketching of the contours within the limits of error that may be prescribed.

The same details are obtained in the Coast and Geodetic Survey with the plane table, the elevations being determined with the vertical

are, and the shore lines and roads being located directly by plane table stations over the whole area, only such traverse lines being run, and these almost invariably with the plane table, when a strip of country is encountered in which plane table stations can not be made, for instance, a dense wood in such a level region that it is impossible to see out to the determined points.

This statement shows that in the method employed by the Geological Survey the ground has to be covered at least four times, and it may happen five times, whereas, in the method of the Coast Survey, it is covered but twice. It seems to me that this, in itself, is such a saving of time that there can be no question as to the preference of the Coast Survey method in conducting work such as is required in the Coast and Geodetic Survey; that is, a large scale, with intricate shore lines and details of high cultivation, to be represented on the map. But the method of the Geological Survey is still further objectionable, if we should attempt to apply it to our own work; for the labor of plotting the traverse lines and details involves in work of such intricacy as ours an amount of time that is almost equal to the time consumed in making the survey in the field. It may be observed, also, that the method of the Geological Survey would be most laborious and almost impracticable in determining many of the shore lines on the New England coast with the degree of accuracy that is required. There can be no doubt that this feature in surveying is more rapidly and economically traced by the plane table, and that in many instances it is the only instrument with which a control of the shore can be satisfactorily obtained.

In discussing these methods I am led to the opinion that to adopt the methods of the Geological Survey, as they have been given to us by Mr. Gannett, as a substitute for our own in the prosecution of topographical surveys for the Coast Survey, would lead to an increase in the cost of the topography per square mile so large that it would practically be prohibitive.

While considering this question of methods I ask your indulgence for a few moments longer to express my views on section 4 of the Superintendent's opening address to the conference.

We have already expressed ourselves most forcibly that in our own topographical work we can see no very material modification that can properly be made, either in the detail that is given or in the method that we employ; that we believe experience has fully demonstrated the economy of our methods, and that they are superior in accuracy and rapidity for the same class of work over any methods employed by any topographers the world over, so far as we have been able to ascertain.

The second part of this section of the Superintendent's address refers to methods for making topographic surveys of less refinement, and to be at a reduced cost. The subcommittee to which was referred the cost

Comparison of methods of making topographical surveys in the U. S. Geological Survey and in the U. S. Coast and Geodetic Survey.

of work has referred to this question at considerable detail in their report, but did not enter into the details of actual methods.

In any region where it is practicable to use the plane table alone it is, in my opinion, the cheapest and most rapid method that has yet been devised, either for an accurate survey or for a survey of less precision, with greater generalization. The cost per square mile, wherever a survey is made with this instrument alone, must depend very largely upon the details that will be shown upon the map, aside from the personal equation or the expertness of the officer manipulating the instrument. There are, however, many regions so densely wooded, and at the same time broken with deep ravines, that it is essential to use some auxiliary instrument to locate details. The methods employed for this purpose on the Geological Survey are at once suggested as those most available in a country of this character; but it should be observed that to use these methods, so far as they relate to detail only, would not produce a satisfactory result, as the work would be very imperfectly oriented in its different parts, rendering directions and distances very uncertain. The Geological Survey has recognized the failure of these methods when used alone, and has strengthened them in the only practicable way by covering the ground with a triangulation of reasonable strength and interpolating other points with the plane table.

The scale on which the survey is made necessarily affects the cost of the work in a general way. If the scale is large, it requires more stations to represent the features that can be shown upon the map. If the scale is small, these features are generalized, to a certain extent, and the number of stations that would be required is less. The advantage, therefore, of the small scale in reducing the cost should at once become apparent. On the other hand, the scale of the work should be sufficiently large to represent a reasonable detail of the features of a country. In the work of the Conference we have given expression to the opinion that a survey should not be made upon a scale smaller than 1–40000; that the generalization required on a smaller scale is too great to preserve the degree of accuracy that should be attained to make the survey useful for the general purposes that a topographical survey may subserve.

To describe in detail the different methods that can be used in covering the country rapidly, but still with sufficient fullness to render all the salient features recognizable, would involve a labor too great to be undertaken by this Conference or any individual upon it. There are new instruments that could be made very useful in such a work; that would modify to some extent methods that have heretofore been used by topographers. But unless there is a specific statement as to the degree of accuracy that shall be required, and the detail that shall be represented, I believe to draw up any plan for such surveying would be labor thrown away.

In conclusion, I have only to say that the expert topographer, with experience behind him in making topographical surveys of precision, is in general well equipped to undertake rapid and inferior work when required. But I do not wish it to be inferred from this statement that the expert topographer is necessarily expert in the execution of inferior work, for, besides the ability to manipulate instruments and to grasp the features of a country, a long experience is required to enable him to present them on a map in the most intelligible form; and therefore, when we wish to reduce the cost of work, I believe it is essential we should consider the experience of the men who may be detailed to execute the work in the field.

My personal experience on the Coast Survey satisfies me that to produce the most economical results we require a school of topography. Young men who may be selected to learn this class of work should be given ample opportunities in different parties on different sections of the coast to learn the individual methods of the more experienced men, before they are permitted to undertake any work by themselves.

SUPPLEMENT L.

FORMULA FOR COMPUTING DIFFERENCES OF ELEVATION—A SIMPLE AND PRACTICAL FORMULA FOR THE COMPUTATION, WITHOUT THE USE OF TABLES, OF DIFFERENCES OF ELEVATION CORRESPONDING TO GIVEN DISTANCES AND SMALL VERTICAL ANGLES, WHEN THE SAME UNIT OF LENGTH IS EMPLOYED FOR DISTANCES AND HEIGHTS.

[By W. C. Hodgkins.]

As is well known, the empirical formula for the computation of heights, given in the Coast and Geodetic Survey treatise on the plane table is based upon the use of the metre as the unit of distance, and of the foot as the unit of height. It is therefore not applicable to the case under consideration.

For ordinary purposes the formula for the difference of height may be stated with sufficient accuracy thus:

$$h = \pm \mathrm{D}.\ \tan \alpha + c \left(\frac{\mathrm{D}}{1000}\right)^2$$

where h represents the difference of the height, D the distance, α the vertical angle and c a constant coefficient of curvature and refraction. If now we call the number of minutes in the angle a and using the metric system take K for the distance in kilometres we have

$$h = \pm \mathrm{D}\ a\ \tan 1' + c.\ \mathrm{K}^2$$

Formula for computing differences of elevation.

The tangent of 1′ is 0·0002909 or $\frac{0{\cdot}2909}{1000}$; therefore

$$h = \pm\ 0{\cdot}291\ \mathrm{K}\ a + c\ \mathrm{K}^2$$
$$\therefore\ h = \pm\ 0{\cdot}291\ \mathrm{K}\ a + 0{\cdot}07\ \mathrm{K}^2$$

c may be taken as $=0{\cdot}07$. Also, 0·291 very nearly equal $\frac{7}{24}$ or $\frac{1}{3}-\frac{1}{24}$ that is, $\frac{1}{3}-\frac{1}{8}$ of $\frac{1}{3}$.

For the first term, therefore, we have the following rule:

Multiply the distance in kilometres by the angle in minutes, divide the product by three, and subtract one-eighth of itself.

The same result would be obtained by taking one-fourth of the product and then *adding* to the quotient one-sixth of itself.

For the second term multiply the square of the distance in kilometres by 0·07.

For angles from zero to 4° the decimal coefficient is more precise than the common fraction, but the latter gives sufficiently close results at all ordinary distances, with angles not greater than 6°.

With larger angles it should be used with caution, and only for short distances, though under such circumstances the errors arising from its use are smaller than if the decimal coefficient were used and are less than half as great as those occurring in similar use of the old formula of the "Treatise." As this coefficient $\frac{7}{24}$ is larger than the decimal coefficient 0·291 by about $\frac{1}{417}$ part of the latter, it gives for small angles results which are larger than the true differences; and as up to about 3° the tangents of angles are sensibly proportional to the angles, this error is greatest with vertical angles of about 3°, when it amounts to 13 centimetres per kilometre.

As the tangents of the angles above 3° increase more rapidly than the angles, the error arising from the use of the coefficient $\frac{7}{24}$ decreases as the angle increases, up to 5° 7′ when the formula is exact (for all ordinary purposes). For still larger angles, the tangents rapidly increase and the formula gives results which are too small by a constantly increasing difference.

Thus at 6° this error is 10 centimetres per kilometre; at 8° it is 54 centimetres, and at 10° 109 per kilometre. With this last angle (10°) the decimal coefficient gives an error of 1·73^{m} and the formula of the "Treatise" an error of 2·88^{m} per kilometre.

Obviously this formula applies equally well with any unit of length, except that instead of K we should use $\frac{D}{1000}$; and to exhibit the details of the operation we may write the formula thus:

$$h = \pm \frac{1}{3}\frac{Da}{1000}\left(1-\frac{1}{8}\right) + 0{\cdot}07\left(\frac{D}{1000}\right)^2$$

SUPPLEMENT M.

A TREATISE ON THE WAGNER TACHYMETER AND TACHYGRAPHOMETER AS MADE AT THE MATHEMATICAL INSTRUMENT WORKS OF OTTO FENNEL AT CASSEL, PRUSSIA, WITH AN INTRODUCTORY ESSAY BY J. L. LIČKA.

[Translated from the German by W. C. Hodgkins, C. E., Assistant, U. S. Coast and Geodetic Survey.]

TRANSLATOR'S PREFACE.

The following pages are translated from a pamphlet published by the makers of these instruments under the title, "Die Wagner-Fennel-'schen Tachymeter des mathematisch-mechanischen Instituts von Otto Fennel in Cassel. Cassel 1886," a copy of which was kindly loaned me by Assistant Edwin Smith, chief of the Instrument Division of the Office of the Coast and Geodetic Survey.

The translation was originally made during the sessions of the Topographical Conference for my own information in regard to these instruments, the special feature of which, the Wagner "projection apparatus," was new to me, as I think it must be to many engineers in this country.

During the last days of the Conference its members had the opportunity to examine personally a theodolite tachymeter of the above make. I was much interested in the instrument, which appeared very well made, but seemed to me unnecessarily heavy and cumbrous. Such a matter of detail might, however, be easily remedied, and while I was forced to agree with the opinion of the other members of the Conference that in its present form it is not adapted to the ordinary field work of the Coast and Geodetic Survey, I am convinced that it would be of great utility in surveys to be plotted on large scales and with much attention to detail. I am inclined to think that the form of instrument to be used with the plane table (the tachygraphometer) would be especially useful in large-scale surveys, as in its use the elevations of numerous points could be rapidly determined without the use of a separate leveling instrument and contours of any desired interval could then be interpolated, while on the ground, with great precision and facility and without the danger of omitting details of form, to which surveys plotted in the office are liable.

In revising the paper for the record, in accordance with the request of the Conference, I have omitted those sections which contain the detailed directions for adjusting the various forms of these instruments and have changed the sequence of others, so that sections 33 and 34, which in the original appear as a supplement, immediately follow the

general discussion of the theory of the instrument. I have also omitted the letters of commendation, of which a considerable number are given, and which attest the high estimation in which these instruments are held by many European engineers.

W. C. H.

WASHINGTON, *April, 1892.*

A REVIEW OF THE TACHYMETER AND TACHYMETRY.

[By J. L. Lička, Engineer at Cassel-Wehlheiden.]

The great attention devoted in recent times to the tachymeter and tachymetry should justify this attempt at a concise but comprehensive description of the instruments and methods employed, a task undertaken by the author at the request of the publishers of the following treatises and carried out with the single purpose of systematizing our views on this subject.

In recent years, we denote by the name "tachymetry" that method of surveying which permits us to obtain the data, as to position and elevation, necessary for the determination of a point on the surface of the earth, by a single pointing upon the telemeter held at a desired point.

In this work the requirements are, rapid and sufficiently accurate measurement, accomplished with the least possible cost rather than with the most extreme precision.

These views are applicable, for example, in the preparation of general or special projects for the construction of roads, railroads and canals, or in working out plans in the domain of agriculture, as in the improvement of land, in joining detached pieces of ground, in the scientific management and utilization of forests, etc. Tachymeters and tachymetry, therefore, early attracted the attention of military and railroad authorities, who require surveys over large areas. For example, it should be noted that the tachymeter with anallatic telescope, invented by the engineer Porro at Milan in the year 1823, and called "clepscykel" or "cleps," was employed in 1835 in topographical surveys by the Piedmontese general staff.

The French engineer Moinot, in the year 1865, skilfully utilized Porro's distance measure in the construction of an instrument adapted to surveys, the tachymeter theodolite, furnished with a compass and with a vertical circle divided according to zenith distances; but he chiefly furnished methods for conducting the work of surveys, computations and mapping, which are to be considered standard, and which serve in great part as foundations for the further development of tachymetry.

Moinot's method, introduced into Austria in 1870 by the engineer Heuser, was employed there with great success in extensive delineation of very broken country. Since then, tachymetry has received

especial attention in Austria, particularly in the general office of Austrian railways at Vienna. Engineers, professors, and mechanicians compete in the construction of new instruments, in the improvement and elucidation of tachymetric surveying methods; all seek to put the engineer in a position to obtain his horizontal and vertical measurements in the shortest practicable time. In North Germany it is conceded that Moinot's method and tachymetry in general have found no greater employment than when about 1867 or 1868 a tachymeter was constructed by the engineer Carl Wagner, at that time in Wiesbaden, which seemed better adapted than other instruments for solving the familiar problems of tachymetry with the least expenditure of time and money; for most of the instruments made since 1871, the sole control of which for Germany had been transferred by the inventor to the mathematical instrument works of Otto Fennel at Cassel, were furnished to other countries, Turkey, Bulgaria, Roumania, etc., where they were used with the best results in studies for railroad locations. To the circumstance that since 1870, extensive preliminary works for railroads have every year become less frequent in North Germany, we may well attribute the fact that the above-mentioned tachymeter was less known than its simple manipulation and advantageous performance of work would lead us to expect. More recently, a change for the better is undoubtedly noticeable, magistrates and technicians engaged in the various fields of road building, of land improvement, and of forestry devoting to these instruments the attention they so well deserve, as is shown by the numerous testimonials to their capabilities.

In order to make perfectly clear the superiority and utility of the Wagner-Fennel instruments, we must state in the first place, at least in general outline, the characteristics of the instruments heretofore used. We shall consider only the most widely-used forms, whose optical distance-measures have wires of constant interval, and shall pass over those instruments more rarely used, in which the distance on the slope is determined by any other means. As already stated, the problem of tachymetry consists in determining in position and elevation, from certain stations, those points of the surface whose location seems desirable, by simply sighting upon the telemeter held at the desired points. The necessary data for this determination comprise the optical measurement of the inclined line of sight, and the measurement of a vertical and of a horizontal angle, which requirements are fulfilled in one way or another in every form of tachymeter. If, at first, we neglect the consideration of horizontal angles, which may be determined in three different ways, by theodolite, compass, or plane table, tachymeters may be classified as follows, according to the means used for determining the reduced horizontal distance and the relative or absolute height.

(1) Those instruments which, by optical distance-measures and vertical circles, furnish simply the data of inclined distances and vertical

angles, from which the horizontal distance of the foot of the rod from the center of the station and the relative height of the observed point from the horizon of the instrument are computed in one way or another.

(2) Those instruments in the use of which the length of the inclined line of sight measured by the distance wires of the telescope is converted at once into horizontal distance and relative or absolute height, by mechanical arrangements upon the surveying instrument, the so-called "projection apparatus."

As the characteristic feature of each of these classes—the vertical circle, and the projection apparatus—may be combined with the various instruments used for measuring horizontal angles, as the theodolite, the compass, and the plane table, six different instruments are possible under the two principal classes mentioned. Of these six instruments, the simple compasses and the plane tables are of subordinate value for measuring horizontal angles. The object of the survey will, in general, determine their use. The addition of sensitive compass needles to the theodolite and plane-table tachymeters will often be very convenient, for reasons which will be mentioned later. And therefore we need give no further separate consideration to compass instruments; because all that can be said of the theodolite tachymeter also finds its appropriate application to them.

There remain therefore to be discussed of the two categories of instruments above mentioned, (with vertical circles and with projection apparatus,) those which determine horizontal angles by the divided circle (theodolites) and those which represent them graphically (plane tables).

I. TACHYMETERS WITH VERTICAL CIRCLES.

The first subdivision of this group is represented by an instrument which will be designated simply as the tachymeter theodolite, and which, besides the usual arrangements for measuring horizontal and vertical angles, has a distance-measuring telescope. The observations which are made in the field on instruments of this class, for the determination of points to be located, give the distance on the slope and the horizontal and vertical angle, not counting as a separate observation the space subtended on the telemeter, from which the inclined distance is determined.

From these data the azimuth of the desired point is first determined, then the reduced distance and the relative height from the point of observation, as already mentioned, by computation or in any other way. It can not be denied that these preliminary computations or mechanical operations, as the case may be, even if conducted by experienced workmen, require considerable time and that the danger of introducing errors of computation, over which we have no control, is proportionately great.

For plotting the points of detail determined by tachymeter, the semicircular protractor proposed by Porro is most convenient. It differs from the usual form in having the graduation numbered from right to left, and in having upon the zero line a scale of distances, which renders it possible to lay down at once, according to scale, the points of detail, without using the compasses or marking the directions with lead pencil.

The above described operations, which refer to detailed surveys with the theodolite tachymeter, are also applicable, with some alterations, to surveys with the plane table and telemetric alidade.

In this case, with respect to the special manner of work with the plane table, *i. e.*, the graphical delineation of horizontal angles, the process of surveying undoubtedly shapes itself in a somewhat different manner than before, since the geometric picture of the surface to be surveyed is developed at once. In this case the line to the desired point is first drawn, then the distance on the slope is read from the telemeter, and finally the angle of elevation as before. Now it is absolutely necessary, for the tachymetric determination of a point, to compute at once in the field, or to determine by one of the methods suggested, at least the reduced distance, in order to be able to plot it upon the spot by compass and scale on the line drawn in the direction of the geometrical position of the point. It is also sometimes necessary to ascertain at the same time the relative heights of the observed points compared to that of the station, to compute the absolute height of the station, and to mark these at the geometrical positions on the map. Since the points surveyed are shown at once upon the plane table in correct position, this method has the great advantage over the use of the theodolite, as regards distribution of points, that during the work itself one obtains a clear idea of the surface to be surveyed and is unlikely to determine either too many or too few points. The cost of plane-table surveys will also, according to actual experience, prove lower than that of theodolite surveys. Therefore, whether considered from a theoretical or an economical standpoint, the plane table has advantages over the theodolite for tachymetric work. Only the fact that the theodolite gives the records of measurements in figures, which permits at any time a new drawing of the survey on any desired scale, while the results of plane-table operations, upon the perishable drawing paper, which is also much affected by the weather, are restricted to one determined scale, is in general to be advanced in favor of the theodolite in tachymetry. The theodolite has also material advantages over the plane table in regard to transportation, setting in position, and the work at the station itself; that is, as compared with the older forms of plane tables and alidades formerly used for cadastral surveys.

But the plane-table tachymeter appears in a much more favorable light, if instead of the old form of alidade we use, for example, an alidade provided with the Wagner projection apparatus shortly to be de-

scribed. When so equipped, plane-table tachymeters deserve full consideration, and will eventually supplant theodolite tachymeters in those cases where the object is to make surveys with little expense and a sufficient approximation to accuracy, and in surveys of a topographical character, where the object of the survey is satisfactorily attained in the production of the map itself.

II. TACHYMETERS WITH PROJECTION APPARATUS.

In these instruments also we distinguish two varieties according as they express horizontal angles in angular measure or by graphical delineation. Although different kinds of such instruments with projection apparatus have appeared, only the Wagner-Fennel tachymeters and tachygraphometers, as the best constructed, have succeeded in securing extensive use. As already stated, both forms of the instrument are so arranged that the horizontal distance and absolute height of the point to be determined are read directly from the instrument, after the simple pointing and certain intermediate manipulation, without moving the telescope and without any computation; while in the plane-table form (the tachygraphometer), the horizontal projection of the observed point is plotted in correct position on the plan by pressing an automatic needle arrangement.

The first of these instruments, the Wagner-Fennel tachymeter-theodolite—or, briefly, tachymeter—is a universal instrument in the true sense of the word, and may be advantageously used for tachymetric surveys, for minor triangulation, or for leveling.

In tachymetric detailed surveys with this instrument, four quantities are observed for the determination of each point, viz, the distance on the slope and, after the process of projection, the reduced or horizontal distance, then the absolute height, and finally the azimuth angle. The manipulation of the instrument in the field work is very simple and, after a certain amount of practice, proceeds very rapidly. The instrument is adjusted over the occupied station and the absolute height of the latter is set upon the scale of heights.

The determination of separate points from each station then proceeds as follows. The rodman sets the telemeter at the desired point, the observer at the instrument brings the middle wire upon the zero point of the rod, reads the space on the rod intercepted between the distance wires of the eyepiece, and records in his notebook the corresponding inclined distance. Then he sets off this inclined distance upon the rule parallel to the line of sight, pushes the projection angle against the vernier of heights, and from the latter reads the absolute height and from the horizontal rule the reduced distance of the observed point.

Finally, the horizontal angle is read off, in which one can generally limit himself to one vernier and to reading whole minutes. The read-

ing of the four quantities, the inclined and the horizontal distances, the height, and the azimuth take up about a minute and a half, or at the most two minutes of time, if the observer at the same time undertakes the necessary settings and the record of the results of the measurements and if only one rod is used.

The performance of work can, however, in proportion to experience, be materially increased if two observers work with one instrument and at the same time employ two rodmen. In consequence of this, the engineer conducting the sketching, who thoroughly understands at the same time the management of the survey, must develop a correspondingly high production of work if desirable results are to be obtained from all persons employed.

From the preceding remarks it ought not to be difficult to draw the conclusion that the Wagner-Fennel tachymeter-theodolite is superior to the ordinary instruments of its class, and we believe our views will be supported by the unanimous opinions of all those who have made extensive surveys with both kinds of instruments. As regards the second characteristic instrument of this class, the Wagner-Fennel tachygraphometer, we can make a brief reference to what has already been said, and enter into an account of the instrument alluded to only so far as necessary for the comprehensive description of the tachymeter. All necessary explanations in regard to setting up this instrument will be found in § 25 of the following treatise.

The survey itself is conducted in the same way as with the theodolite-tachymeter, except that the horizontal distance of the observed point is not first read off, but is plotted directly upon the plane-table sheet by an automatic attachment with movable needle, and in true relative position, according to scale. At the geometrical position of the point thus obtained we mark its absolute height, read directly from the instrument.

As regards rapidity of work, the tachygraphometer even surpasses the theodolite with projection apparatus, for according to the statements of a professional man certainly in this respect most noteworthy, the inventor himself (Carl Wagner, "Ueber die Hilfsmittel der Tachymetrie, insbesondere über die Vorzüge der schiefen Lattenstellung." Zeitschr. f. Verm., Bd. xv., Heft 14 u. 15), the field work with the tachygraphometer takes no longer and, all things considered, less time than with the theodolite or with any other instrument adapted to tachymetric surveys, since with the tachygraphometer we obtain the reduction of the inclined distance as well as the plotting of the desired point, directly, as an immediate result.

III. TACHYMETRIC SURVEYS.

With special reference to tachymetric surveys, we need not, in considering the numerous monographs, articles in periodicals, and handbooks of surveying, pursue the subject further than appears desirable

for explaining the manipulation and advantageous use of the Wagner-Fennel instruments. For further information we may chiefly refer to the excellent general account in Jordan's Handbuch der Vermessungskunde, Stuttgart, 1877, Bd. I, S. 626 ff., which we here for the most part follow in essential points.

The field work of tachymetry consists, as already stated, in determining, by measurements of distance, azimuth, and height, the points desirable for the actual object of the survey from certain other points which serve as stations for the tachymeter.

To determine the positions and altitudes of the tachymeter stations we may employ any of the exact methods of horizontal and vertical measurement, as triangulation, in connection with trigonometric leveling, or the regular system of traversing in polygons in connection with spirit leveling, or we may simply connect the single stations with each other by tachymeter.

These are in general the extreme methods, which, however, may be combined in various ways so that, according to the greater or less pains taken in the accurate determination of the stations, a correspondingly different degree of precision will be attained in the elements determining their position and height.

A scheme of minor triangles, with simultaneous trigonometric leveling, cannot always be laid out, especially in extended forests, with figures sufficiently small to furnish in this way all necessary stations for the tachymeter; one is often compelled to lay out a string of main figures and others of subordinate importance, in order thereby to first obtain principal stations with which other approximate stations may be connected by tachymeter. Whether, in such a series or main scheme, the relative heights should be determined by level or by vertical angles depends chiefly upon the amount of the relative differences of height between the stations directly connected; in flat or rolling country leveling is advisable on account of its exactness, but in mountainous regions, with constant changing of instrument and short sights, leveling no longer commends itself, and we then measure the vertical angles for all the lines (preferably in both directions), at the same time with the measurement of horizontal angles.

The principal differences of height are best computed exactly, by logarithms, in connection with the computation of the coördinates of the points of the polygons, and the possible errors of closing are distributed in the connected series on both sides in proportion to the lengths of lines. In steep mountainous country, one is frequently compelled to run out the traverses of the sides of the polygons with the tachymeter.

A series of polygons with leveled stations commends itself, then, for the tachymetric survey of the ground, if it is a question of the survey

of a strip of country from 200 to 500 metres wide for laying out a railroad, a road, or a canal.

In this case, using a general preliminary outline prepared upon the basis of previous topographic maps and careful reconnaissances, we trace out in the field a series of polygons (primary series, called also basis of operations) lying near the most probable location. Since we can read from the separate stations up to 300 metres distance with the telemeter the single stations of the series may be as much as 600 metres apart, which would be perfectly practicable and useful in entirely flat country, but in the mountains the mean distance between any two stations must generally be much smaller; distances of from 200 to 400 metres should be the rule under mean conditions.

The scale divisions of the Wagner-Fennel instruments are arranged for distances up to 200 metres, with the assumed scale of 1–1000, which does not, however, prevent working at greater distances, though it appears inexpedient to do so.

The different stations of the series of polygons are of course so selected that one can see from any one of them the preceding and following stations and can on all sides overlook as much as possible of the strip of country to be surveyed.

After the selection and careful marking of the principal points, the lines are measured in both directions of the series and the horizontal angles at least twice in each position of the telescope; then the entire series is twice leveled, and from these observations the coördinates and heights of the separate stations of the chain are computed.

If we obtain the horizonal orientation by a simple traverse, sighting on the last station, we do not use the compass, strictly speaking, at all, but we can employ it for reading off the approximate azimuth, which is of material advantage for a general check on the plotting. For the purposes of the detailed survey, field sketching sheets are prepared, showing the series of polygons plotted in the usual way by rectangular coördinates; then the detailed survey can proceed upon a secure foundation by means of the simple tachymeter and without further difficulty.

If one does not in the first place systematically determine and mark the primary stations, but merely connects the different stations with each other tachymetrically, generally without marking them, one should at all events measure all the connections between every two points in distance, azimuth, and height, reciprocally in both directions, and thus obtain a control in the field, so as not to run the risk that through an error in the connection of two stations all the work which is done at one or more stations should be lost. The series of polygons which connects the stations should not be left unchecked. Such a series not selected in the beginning, and hence not commonly marked, should therefore, at all events at the end of the work be verified by separate

measurement (for example, by the three point problem or back intersections from at least two compass bearings).

As concerns the survey of details, the most important points have already been discussed in connection with the use and manipulation of the tachymeters in question.

The selection and the number of points to be determined will vary with the character of the country and the degree of precision required, which in turn is governed by the object of the survey.

With regard to the plotting of tachymetrically determined points, and also the further elaboration of tachmetric surveying, which is all conducted in the same way as in the use of an ordinary theodolite (engineer's transit), the following works may be referred to:

Jordan, Handbuch der Vermessungskunde, Band I. Stuttgart, 1877.

Werner, Die Tacheometrie und deren Anwendung zu Tracestudien. Wien, 1883.

Heusinger von Waldegg, Handbuch der Ingenieur-Wissenschaften, Band I. Leipzig, 1883.

Hartner-Wastler, Handbuch der niederen Geodesie. Wien, 1885.

With .regard to the precision of optical measurement of distances, the following is also well worthy of attention:

R. Wagner, Ueber die mit dem Reichenbach'schen Distanzmesser erreichbare Genauigkeit und einige Erörterungen über die Fehlerursachen desselben. Zeitschrift für Vermessungswesen, Band XV. Heft 3, 4, 5. Stuttgart, 1886.

INTRODUCTION.

With the instruments commonly used in tachymetric work—theodolites with telescopes arranged for measuring distances and with vertical circles for determining heights—it is necessary to compute the coördinates of the point at which the rod is held from the distance on the slope, obtained from the space subtended on the rod.

The instruments hereafter described aim at a saving of these time-consuming computations by giving a direct reading from the instrument of the coördinates of the point observed upon.

The length of the inclined line of sight is measured by means of the distance wires of the eyepiece, and then the horizontal distance from the center of the station to the foot of the rod and the absolute elevation of the same above sea level are read from the instrument, without any computation; or in a similar way, when using the plane-table form of the instrument, the horizontal projection of the observed point is pricked upon the drawing in its correct position by pressing down a needle suitably arranged.

Thus in tachymetric work, horizontal angles may be measured in three different ways—by theodolite, by compass, by the plane table—and hence three different constructions of this tachymeter are provided.

The same characteristic, the Wagner projecting apparatus, is common to all, and, therefore, in the following pages the description and theory of this projecting apparatus are first given.

THE PROJECTING APPARATUS, ITS THEORY AND MANNER OF USE.

SECTION 1. To the telescope of the tachymeter, which is provided with distance wires, a rule *AA* (illustration No. 32), bearing a scale of distances, is attached by two arms, one of which is fixed to the axis of the telescope outside of the bearing and the other near the objective and so that the straight upper edge and the face of the rule are parallel to the vertical plane in which the telescope moves in altitude. In any position of the telescope the upper edge of the rule has exactly the inclination and direction of the line of sight. Upon this rule moves a slide *S*, held in place by an automatic spring clamp, and carrying two verniers. The upper vernier *a* serves for reading from the scale of heights *DE* of the projection angle, when the latter is pushed against the contact edge of the vernier. But in order to be able to do this with any inclination of the rule, the vernier *a* is capable of rotating on an axis which, as is easily proved, must lie exactly in the contact edge. Therefore, in any inclined position of the rule the vernier *a* may be made parallel to the scale of heights; that is, vertical. The lower vernier *b* remains fast to the slide and is used for the exact setting of the inclined distances, in reduced scale, upon the rule. If the zero point of this vernier be set at the zero point of the scale, the axis of rotation of the vernier *a* lies in the prolongation of the axis of rotation of the telescope.* Therefore in any other position of the slide, the interval at right angles between the two axes may be read from the scale, or, conversely, any desired value may be given to this interval by setting the slide.

SEC. 2. Nearly perpendicularly below the rule just described is a second rule *BB*, also provided with a scale of distances and so attached that its face is parallel to that of the upper rule and that its upper edge remains horizontal. Upon this upper edge, which is always horizontal when the instrument is in use, is placed a movable right angle *CDE*, upon the vertical edge of which is a scale for reading heights, which scale can be moved vertically about 1·5 centimetres, by the micrometer screw *E*. In any given position of the right angle, this scale of heights is in the same vertical plane as the vernier *a*. The numerical values for this scale are written with lead pencil for every 10 units upon a small strip of ivory, and when the height of the station is changed are easily erased and replaced by others. Thus the same result is attained as by a great motion of the scale itself, while the exact setting to single

*As will later be shown in section 6, the position of the vernier *b* is actually slightly different. Nevertheless in sections 3 and 4 the above statement is retained for the sake of simplicity.

THEODOLITE TACHYMETER.

units and fractions is accomplished by means of the micrometer screw *E* and the vernier *d*. For example, if the scale is to be set for a given elevation of 237·40, we mark one of the even tens nearest to the zero of the vernier *d* 230 (Fig. *a*), and then by the screw *E* move the whole scale until the vernier reads 7·40 units, in addition. With the telescope horizontal, both verniers, *d* and *a*, then give the same height, 237·40 (Fig. *b*).

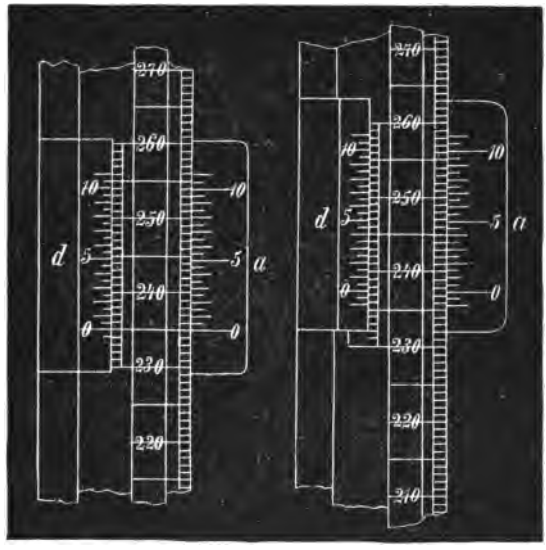


FIG. *a*. FIG. *b*.

In order to facilitate the sliding motion of the projection angle, the ends of its lower surface *CD* are supported on friction rollers. Then at *i* is an automatic spring clamp by which the projection angle is held fast in any position, and finally at *c* is a vernier which serves for reading the reduced horizontal distances. When this last vernier is set at zero on the scale *BB*, the forward edge of the scale of heights *DE* is exactly in the vertical plane passing through the horizontal axis of the telescope. If, therefore, the projection angle is pushed forward until the scale of heights meets the contact edge of the vernier *a*, the horizontal projection of the distance between the axis of the vernier *a* and the horizontal axis of the telescope may be read directly from the vernier *c*, and the vertical projection of this distance appears on the scale of heights as the difference of the verniers *a* and *d*.

SEC. 3. In order to explain the theory and use of this projection apparatus, let us imagine two straight rules lying in a vertical plane and capable of rotation about a common point *O* (fig. c.), the upper edge *AA* of the one being directed by a sighting arrangement upon a point *P*, to be determined, while the upper edge *BB* of the other is retained

in horizontal position by a level. Then if the length Oa corresponds in any known relation (reduced scale) to the distance OP, and if, further, CDE be a right angle (projection angle) movable upon BB, then

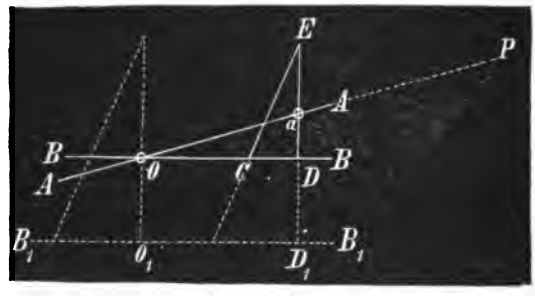


FIG. c.

OD is evidently equal to the horizontal projection and AD to the vertical projection of Oa and only the arrangement of suitable graduations is necessary in order to be able to read these values directly with satisfactory exactness.

If the second rule, while still in the vertical plane of the first, instead of remaining at BB is brought into any desired position parallel to BB, as B_1B_1, we still preserve (with a correspondingly lengthened projection angle) the horizontal and vertical projections of Oa, for from the resulting parallelogram, $OD=O_1D_1$ and $aD=aD_1—DD_1=aD_1—OO_1$.

The distance $OO_1=DD_1$ only comes into consideration in vertical projection, and always as a constant correction, the subtraction of which can be mechanically performed, if this distance, the relative height of the point of rotation O, is marked on the projection angle.

If, for example, the zero point of the graduation upon the projection angle stands at the same height as the point O, then the former also corresponds with the point D; and Da (in the same way the relative height of the point P sighted upon) can be read directly from the graduation in correspondingly reduced scale.

SEC. 4. If we add the relative height of P to the absolute height of the point O, referred to any horizontal plane, we shall obtain the absolute height of the point P. But this addition is not obtained by computation but by mechanical means, assigning to the point O the absolute height of the station. Then the point D on the scale of heights corresponds to the absolute height of the station and by reading off at a, the addition of Da is accomplished without separate manipulation, and therefore the absolute height of P is obtained. Hence it does not enter into consideration whether P lies above or below the horizon, for in the latter case a subtraction of the relative height follows, as is easily indicated by a corresponding alteration of the figure.

The procedure necessary for moving the scale of heights in setting for the absolute height of the station is given in section 2, above.

On the Wagner-Fennel Tachymeter and Tachygraphometer.

Finally, it should be suggested that the points O and a are understood to represent the geometrical axes of revolution of the telescope and of the vernier a.

SEC. 5. In the use of a tachymeter-theodolite, whose telescope is arranged for the use of the telemeter and with the rod held at right angles to the line of sight, we obtain, as is well known, the horizontal distance E between the foot of the rod and the station point by the formula,

$$E = (C.L + c) \cos \alpha + S. \sin \alpha \quad . \quad . \quad . \quad . \quad (1)$$

in which, L is the interval read from the rod,
C is the constant factor, as 100 or 200, for example,
c the additive constant, equal to the distance from the center of the instrument to a point at a distance in front of the objective equal to its principal focal distance,
α the angle which the central visual ray makes with the horizon,
S the height of the target above the ground.

It will now be shown that we obtain from the tachymeter with projection apparatus a similar graphical derivation of this formula and the process by which it is found will be given.

The addition of the constant c to the product CL, which is easily obtained from the rod-reading and set off upon the scale AA by means of the vernier b, is accomplished always in a mechanical way if the vernier b is so corrected, once for all, that it reads $-c$ when the contact edge and axis of revolution of the vernier a lie in one vertical plane with the horizontal axis of the telescope.

Then also in the corresponding position of the projection angle the vernier c stands at zero upon the lower scale, from which the reading of the horizontal projection is taken, while in any inclined position of the telescope one will read a horizontal distance which is greater by $c \cos \alpha$ than would be the case without this correction. The actual amount of this correction must evidently be equal to $\frac{c}{n}$, if n denotes the reduced proportion of the scale.

SEC. 6. In order also to bring the term $S. \sin \alpha$ into calculation by mechanical means, the axis of rotation of the vernier a is so arranged that in the horizontal position of the telescope it lies below the horizontal axis of the telescope at a distance equal to $\frac{S}{n}$. If this condition is satisfied, not only is the term $S. \sin \alpha$ brought into consideration in taking off the projection, but we also obtain the height of the distant point compared to that of the station, correctly within the limit $J - S$ (where J is the height of instrument above ground and S that of the target).

Figure *d* serves as a demonstration, and in this figure

V denotes the zero point of a telemeter at *P*,

O denotes the horizontal axis of the telescope,

OV denotes the line of sight (determined by the middle wire) to which the telemeter is held perpendicular,

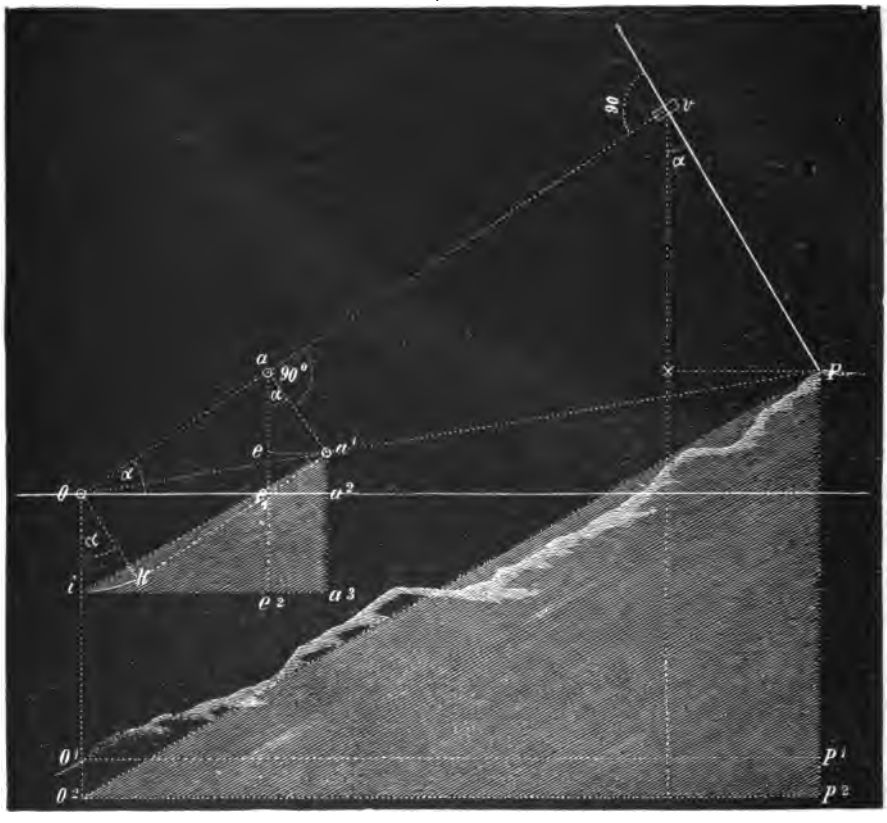


FIG. *d*.

α denotes the angle of inclination of this line of sight to the horizon, and

$\frac{1}{n}$ denotes the reduced scale of the divisions on the rules;

further let

$OO_1 = J =$ the height of instrument, *i. e.*, the vertical distance from the axis of the telescope to the ground.

$PV = OO_2 = S =$ the height of the signal, *i. e.*, the distance from the foot of the rod to its zero point,

$Oa = \frac{OV}{n}$.

On the Wagner-Fennel Tachymeter and Tachygraphometer.

If we now draw aa at right angles to OV, and also make $aa_2 = Ok = Oi = \frac{S}{n}$, ka will represent the line, parallel to the line of sight, in which the point of rotation of the vernier a (section 1, illustration No. 32) moves when the slide is moved along the rule. When the distance is zero and the line of sight horizontal, this point of rotation of the vernier falls upon i.

For the distance on the slope, OV, the setting of the vernier b (section 1, illustration No. 32) to $\frac{OV}{n} = ka_1$ gives on the rule AA the point a_1 and the distance Oa_1 must evidently, from the similarity of the triangles Oa_1a and OPV, be equal to $\frac{OP}{n}$. If now Oa_1 be projected upon the horizontal, we obtain the length.

$$Oa_2 = ia_3 = Oe_1 + e_1a_2 = Oa.\cos\alpha + aa_1 \sin\alpha = \frac{OV}{n}.\cos\alpha + \frac{S}{n}.\sin\alpha$$

$$= \frac{1}{n}\left[(C.L + c)\cos\alpha + S.\sin\alpha\right] = \frac{1}{n}E$$

By this process then we obtain the horizontal projection of the distance OP, in the reduced scale adopted, corresponding to the formula (1), section 5.

SEC. 7. The difference of height between Q_1 and P is $PP_1 = H$. If we suppose that in Fig. *d*, $OO_2 = VP = S$ and that the connecting right lines ia_1 and O_2P are drawn, then the figures Oia_1a and OO_2PV are similar, whence it follows that ia_1 is parallel to O_2P and that $ia_1 = \frac{1}{n}.O_2P$.

Further, it appears from the similarity of the triangles ia_1a_3 and O_2PP_2, that $a_2a_3 = \frac{1}{n}PP_2$; that is to say, from the vertical projection of the point a_1 we obtain in a_1a_3 the reduced measure of PP_2.

If this be converted into the natural scale and if $J-S$ be added thereto, we then obtain the difference of height between O_1 and P;

$$H = PP_2 - P_1P_2 = PP_2 - (S - J) = PP_2 + (J - S)$$

But the addition of $J - S$ can also be made in a mechanical way upon the instrument, as long as one works with a constant height of instrument.

If one takes the height of instrument equal to that of the signal (the height of the zero point of the rod), which always amounts to $1{\cdot}5^m$, then $J - S = 0$, and this correction is in general unnecessary. If, however, the height of instrument is not equal to that of the signal, then we bring the difference $J-S$ into account by so moving the vernier *d*, when the telescope is horizontal, that its reading upon the scale of

heights differs from the vernier a by $\frac{J-S}{n}$. With a negative value for $\frac{J-S}{n}$ the vernier d must be moved up and with a positive value it must be moved down.

The vernier d is attached to the projection angle by two small screws passing through elongated slots so that it may be moved in a vertical direction, if the screws are loosened a little.

If, for example, the assumed instrument height of $1{\cdot}5^{m}$ were too great, on account of an observer's smaller stature, and were reduced to $1{\cdot}25^{m}$, consequently $J - S = -0{\cdot}25^{m}$, and the vernier d must be moved up $0{\cdot}25^{mm}$ if $n=1000$, and thence $\frac{J-S}{n} = -0{\cdot}25^{mm}$.

If, then, the scale of heights be set for the height of the particular station by the vernier d and the height of the observed point be read from the vernier a, the latter value will be smaller by $0{\cdot}25^{mm}$, (corresponding on the scale used to $0{\cdot}25^{m}$), than would have been the case without this correction. Should it for any reason be impracticable to work with a constant height of instrument, the difference $J-S$, which for any one station is a constant, could be allowed for in setting the scale of heights to the absolute height of the station.

If, for example, the height of the station is $254{\cdot}6^{m}$ and the height of instrument is $1{\cdot}3^{m}$, then $J - S = 1{\cdot}3^{m} - 1{\cdot}5^{m} = -0{\cdot}2^{m}$ and therefore the height assigned to the instrument in setting the scale of heights is $254{\cdot}4^{m}$. If one prefers not to use this method, the difference $J - S$ is to be added algebraically in the usual way to the height of the observed point, read from the vernier a.

SEC. 8. (Superseded by the addendum given in the regular order, but translated here for comparison.)

It follows, from the description and theory, that the use of the projection apparatus consists simply in this, that the slide with the vernier b is set at the graduation corresponding to the distance read off, then the projection angle is pushed against the vernier a, when the height and distance horizontally of the point sighted upon are read from the verniers a and c, respectively.

If one has read a distance on the rod for which the graduation of the scale is insufficient, one divides the distance into two parts, reads the height and horizontal projection for each part, and adds these together. For example, if the distance read is $287{\cdot}3^{m} = 200^{m} + 87{\cdot}3^{m}$, we set off, first, upon the upper rule 200^{m}, read the corresponding height and horizontal distance, then set off $87{\cdot}3^{m}$ upon the upper rule, read also the height and horizontal distance corresponding to this distance, and add the numbers so obtained, and thus obtain the coördinates of the point sighted at. A consideration of Fig. e, in which D, H, E denote the entire inclined distance, the height and the horizontal projection,

and d_1, d_2, h_1, h_2, e_1, e_2, denote the corresponding partial distances and heights, respectively, will at once show the correctness of the rule.

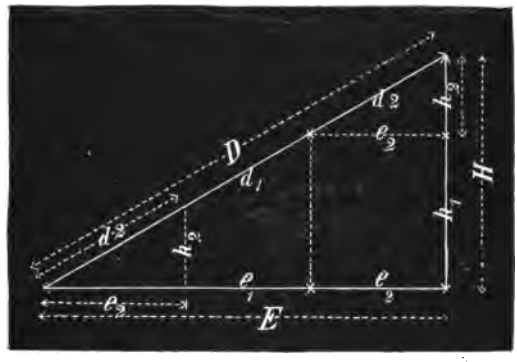


FIG. *e*.

SEC. 9. In cases where it is not practicable to hold the rod at right angles to the line of sight, it may be held vertically. Then the inclined distance is read as usual, set off upon the upper rule, the corresponding horizontal projection read off, this last distance set off once more upon the upper rule and projected the second time, and we then obtain the desired horizontal projection of the point sighted upon. If in the vertical position of the rod the inclined distance was found equal to D, then its horizontal projection is evidently $E = D.\cos^2 \alpha$.

But one obtains exactly the same result by the double projection.

In Fig. *f*, let $Oa = \frac{D}{n}$, then $Ob = Oc = \frac{D}{n} \cos \alpha$, the first projection of $\frac{D}{n}$.

Exactly in the same way $\frac{E}{n} = Oc \cos \alpha = \frac{D}{n} \cos^2 \alpha$, which agrees with the form given above.

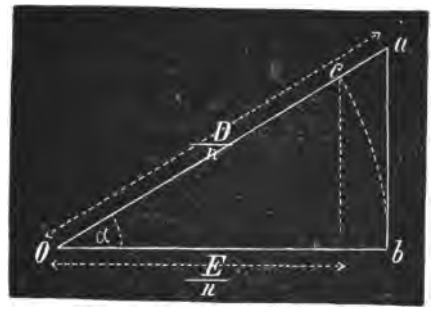


FIG. *f*.

NOTE.—Sections 8 and 9 of this treatise have been superseded by the following addendum:

COMMUNICATION FOR THOSE USING THE WAGNER-FENNEL TACHYMETER AND TACHYGRAPHOMETER.

CASSEL, *May 16, 1890.*

OTTO FENNEL,

Mathematical and Mechanical Institute, Cassel:

In the treatise, "Die Wagner-Fennel'schen Tachymeter des Mathematischen Mechanischen Institutes von Otto Fennel, in Cassel, 1886," there are in sections 8 and 9 some inaccuracies concerning the use of the Tachymeter at distances over 200 meters and in the use of the rod held vertically. It is therefore necessary in these cases to proceed with the survey *not* as stated in sections 8 and 9, but according to the following rule. The detailed proof of this rule, as well as a new demonstration of the theory of the projection apparatus, will shortly be made known in Appendix II:

I.

In order to project a distance which is greater than 200 metres and less than 400 metres, one sets off upon the telescope rule the half of this distance, reads off the corresponding horizontal and vertical projections E_1 and H_1, doubles them, sets at zero on the telescope rule, reads once more the corresponding horizontal and vertical projections e_1 and h_1, and subtracts the same from the values $2E_1$ and $2H_1$.

Example.

Height of station=47·8m. : z=0·1m. : Ar=47·7m.

Rod readings { Upper wire at the zero point. / Middle wire at 1·836 (check reading). / Lower wire at $3{\cdot}673 \times \frac{1}{2} = 1{\cdot}8365$.

Setting on the telescope rule = half distance = 183·65m.

Horizontal projection.	Vertical projection.
$E_1 = 181{\cdot}45$	$H_1 = 52{\cdot}10$
$2\ E_1 = 362{\cdot}90$	$2\ H_1 = 104{\cdot}20$
$-\ e_1 = -0{\cdot}85$	$-\ h_1 = -47{\cdot}80$
$E = 362{\cdot}05$	$H = 56{\cdot}40$
True horizontal distance.	True difference of elevation.

II

If one has observed upon the rod held vertically, he obtains the horizontal and vertical projections of the distance by setting off the observed rod-reading upon the scale attached to the telescope, by reading its horizontal projection E_1, by setting off this reading again upon the telescope scale, and by reading off the corresponding horizontal projection E_2 and vertical projection H_2. Next one sets at zero on the telescope scale, reads off the horizontal projection e_1, subtracts there from the additive constant c, sets off $e_1 - c$ upon the telescope scale,

and reads the corresponding horizontal projection e_2 and vertical projection h_2. Now one subtracts e_2 from E_2 and h_2 from H_2, and adds to the latter value the reduced height of station, Ar.

Example.

$c = 0{\cdot}5$ m for all Wagner-Fennel tachymeters

Height of station $= A = 51{\cdot}65$m : $z = 0{\cdot}05$: $A - z = 51{\cdot}60$.

Rod reading { Upper wire, zero, Lower wire, 1·729.

Setting on the telescope scale = 172·9 m.

Horizontal projection.		Vertical projection.	
$E_1 =$	165·65	$H\,2 =$	102·15
$E_2 =$	158·75	$-\,h\,2 =$	51·70
$e_1 =$	1·05	$+\,(A - z) =$	+ 51·60
$e_1 - c =$	0·55		
$-\,e^2 =$	− 1·50	True height $H =$	+ 102·05

True horizontal distance $E = 157{\cdot}25$

Appendix containing the derivation of the formula assumed as known in sections 5 and 9.

SEC. 33. The distance-measuring telescopes of the Wagner-Fennel tachymeters do not differ materially from those commonly employed in geodetic instruments, except that the diaphragm carries, besides the usual cross hairs, two additional parallel horizontal wires (distance lines), one above and one below the central horizontal line, and at equal distances from it.

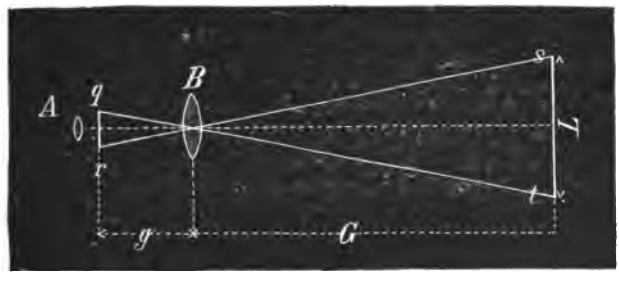


FIG. *g*.

In Fig. *g*.

A is the eyepiece;

B, the objective of a tachymeter telescope;

f, the focal length of this objective;

$l = q\,r$, the portion of the plane of the image included between the two distance wires;

L, the portion of a telemeter which is intercepted between the two planes of rays $q\ t$ and $r\ s$ passing through the distance wires, and further;

G, the distance of the telemeter from the objective;

g, the distance of the image from the objective, and consequently

$$\frac{L}{G} = \frac{l}{g} \quad \ldots\ldots\ldots\ldots \quad (1)$$

According to a fundamental equation of optics we have also

$$\frac{1}{G} + \frac{1}{g} = \frac{1}{f} \quad \ldots\ldots\ldots\ldots \quad (2)$$

By means of these two equations the desired distance G may be deduced from L, l, and f, which are assumed to be known, in the following manner:

From equation (1) $\frac{1}{g} = \frac{L}{G.l}$

If we substitute this value in equation (2) we have

$$\frac{1}{G} + \frac{L}{G.l} = \frac{1}{f}$$

Multiplying both sides by $G.f$ and transposing, this becomes

$$G = f + \frac{f}{l} . L \quad \ldots\ldots\ldots\ldots \quad (3)$$

The value $\frac{f}{l}$, by which the part of the rod appearing between the wires is to be multiplied, forms the so-called multiplication constant, which is hereafter denoted by C, and by the introduction of which equation (3) takes the following form:

$$G = C . L + f \quad \ldots\ldots\ldots\ldots \quad (4)$$

in which G denotes the distance of the rod from the objective.

In order now to obtain the distance from the center of the instrument to the rod, hereafter denoted by D, the distance i from the horizontal axis of the telescope to the objective is to be added to every distance. Equation (4) then becomes

$$D = C . L + f + i \quad \ldots\ldots\ldots\ldots \quad (5)$$

The amount $f+i$ denotes the distance of the forward principal focus of the objective from the center of the instrument, the so-called addition constant, which is generally denoted by c. If we introduce this value in equation (5) it becomes

$$D = C . L + c \quad \ldots\ldots\ldots\ldots \quad (6)$$

SEC. 34. We have next to investigate the method by which, with the line of sight inclined to the horizon and with the telemeter held at right angles to the line of sight, we obtain the horizontal projection E

of the distance on the slope from the centre of the station to the foot of the rod. For this we use Fig. *h*, in which

O denotes the center of the instrument;

V the zero point of the telemeter;

P the foot of the same;

L the space on the rod intercepted between the distance wires, and α the angle of inclination which the central ray *O V* makes with the horizon.

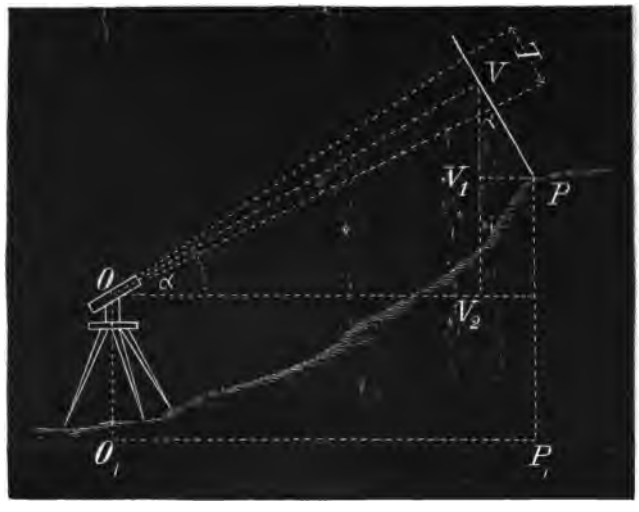


FIG. *h*.

If in addition we call the horizontal projections of the points *O*, *V*, and *P*, respectively, O_1, V_1, V_2, and P_2, and the distance from the zero point to the foot of the rod *S*, the desired distance $O_1 P_1$ is easily obtained, as follows, from equation (6) of section 33:

$$O\ V = C.\ L + c$$

and therefore

$$O\ V_2 = (C.\ L + c.) \cos \alpha$$

and

$$V_1\ P = S.\ \sin \alpha.$$

Adding these last two equations and considering that

$$O\ V_2 + V_1\ P = O_1\ P_1 = E,$$

we obtain

$$E = (C.\ L + c) \cos \alpha + S.\ \sin \alpha \quad . \quad . \quad . \quad (9)$$

This is the formula given in the beginning of section 5, upon which is based the discussion in sections 5 and 6.

In section 9 we have discussed the case where the condition of the ground constrains us to depart from the customary position of the rod at right angles to the line of sight and to hold it vertical.

This case is shown in Fig. *i*, in which O, O_1, V, P, P_1, L, s t, have the meanings already assigned them in sections 33 and 34.

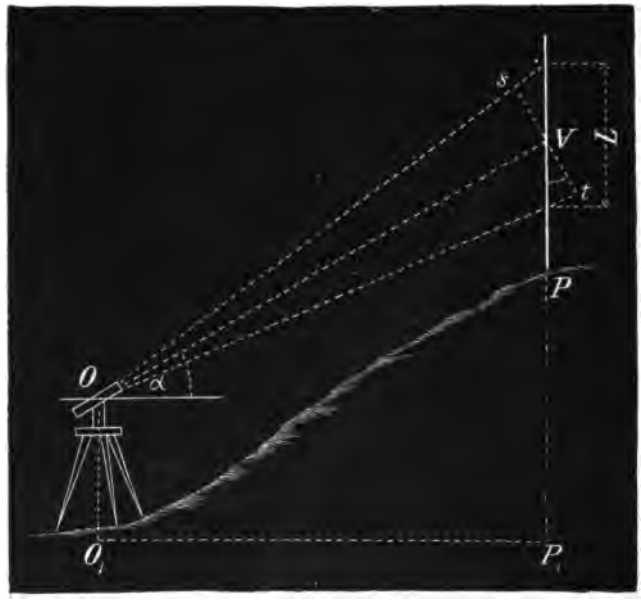


FIG. *i*.

$$s\ t = L.\cos\alpha$$

and therefore

$$O\ V = C.\ L.\cos\alpha + c \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

or approximately

$$O\ V = (C.\ L + c)\cos\alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

(With $c = 0{\cdot}5$ m. and $\alpha = 10°$, the difference between formulas (10) and (11) amounts to 0·005 m., with $\alpha = 25°$ to 0·045 m., with $\alpha = 45°$ to 0·145 m).

If, as in equation (6) of section 33, we denote the factor $(C.\ L + c)$ by D, equation (11) assumes the form

$$O\ V = D.\cos\alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

If now we once more denote by E the horizontal projection $O_1\ P_1$ of $O\ V$, we obtain

$$E = O\ V.\cos\alpha$$
$$= D.\cos^2\alpha$$

as the formula, the graphical demonstration of which by the projection apparatus was explained in section 9.

DESCRIPTION OF THE TACHYMETER WITH REPEATING CIRCLE.—(Tachymeter-theodolite.)

SEC. 10. The construction of the tachymeter with repeating circle is shown in a general way in illustration No. 32. The telescope is of 35 centimetres focal length and has a magnifying power of 31. It has cylindrical pivots resting in Y-shaped bearings, can be easily moved and reverses by the eye end. The covers of the bearings have openings so arranged that a striding level can be placed upon the pivots, for the horizontal adjustment of the telescope axis. In order to be able also to take exact levels, a reversion level is attached to the telescope.

The reticule for telemetric measurements is of peculiar construction and so arranged that either of the two outer wires may be brought up to the middle wire.

The horizontal circle, of 15·5 centimetres diameter at the inner edge of the limb, is provided with a cover, in order to perfectly protect the graduation from defacement and from flying dust. The openings for the verniers are covered with glass plates. The graduation is made, as desired, either sexagesimal (360°) to 20′, with verniers reading to 30″; or centesimal (400°) to 50′, with verniers reading to 1′. The axes are of the most perfect construction. The clamps act on the center without touching the circle or the alidade and the slow motion is given by fine-threaded screws, working against springs. The castings are all large and ribbed, in order to obtain the greatest stiffness combined with moderate weight. The fastening of the instruments to the stands is by means of screw bolts. The stands are of a special, new construction. The tripod head consists of a single bronze casting and is therefore of the greatest durability, while the legs are made of the best tough ash. These stands considerably surpass in stability those earlier used, without having a greater weight. The fastening of these instruments in their boxes is so secure that the longest and most severe transportation has no bad effect upon them.

DESCRIPTION OF THE TACHYMETER-COMPASS.

SEC. 18. The tachymeter, for the measurement of horizontal angles by compass, is in its upper construction almost exactly like the one previously described; only the bearings of the telescope axis are different. These have pivots shaped like double cones, which lie in bearings closed by solid covers and therefore can not be taken out of the bearings.

The compass has a needle 11.5 centimetres long and the circle is divided to half degrees. The north and south line is parallel to the plane in which the telescope moves. Upon the compass plate are fastened at right angles to each other the two tubular levels (cross levels), of

which one lies parallel and the other at right angles to the axis of the telescope. The construction of the base and the manner of attachment to the tripod are as usual.

DESCRIPTION OF THE TACHYMETER WITH THE PLANE TABLE.—(Tachygraphometer.)

SEC. 20. The general construction of this instrument is shown in illustration No. 33. The telescope transits between the standards; is of 35 centimetres focal length; magnifies thirty-one times, and has double cone-shaped pivots resting in bearings closed by solid covers.

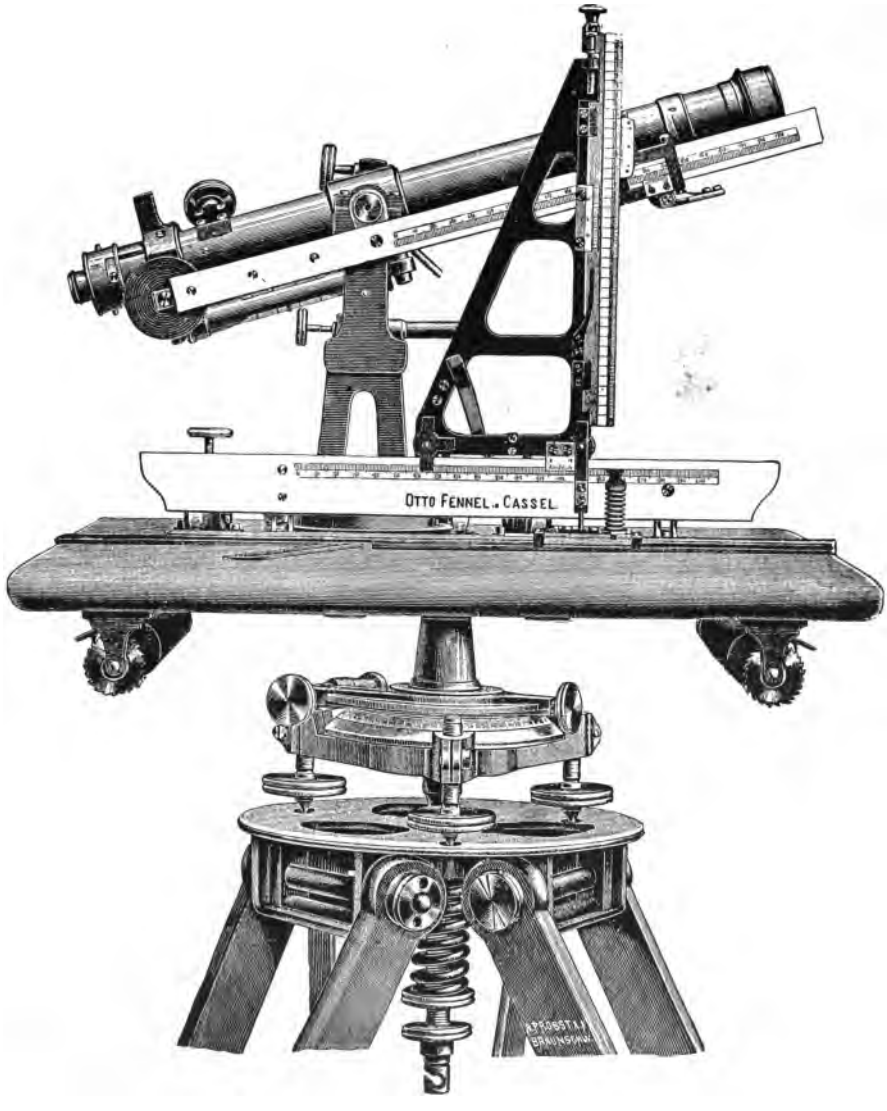
In order to be able to undertake exact leveling the telescope is provided with a reversion level. The eyepiece micrometer is of a peculiar form and so arranged that either of the two outer wires can be brought into contact with the middle wire. The instrument is furnished with two riding levels, one of which is arranged for placing upon the telescope, the other upon the rules. The telescope standard is fastened to the footplate, which corresponds to the rule of the ordinary alidade.

In order to facilitate the motion of the alidade upon the plane table, the footplate is provided with three relieving rollers.

They stand with their axes radial to the axis of rotation of the alidade (which will be further mentioned in section 22) and can by means of vertical set screws be moved so much lower that they project some millimetres below the under surface of the footplate, for which purpose there are corresponding openings in the latter. The rollers not only facilitate the horizontal motion of the alidade upon the plane table but also enable us to keep the alidade in exactly horizontal position while in use, without the necessity of using for that purpose the leveling screws of the table, in the employment of which a new orienting of the table would generally be necessary. One of the relieving rollers has a check screw attached by which the horizontal rotation of the alidade is regulated, *i. e.*, can be made to run easier or harder.

SEC. 21.—The footplate of the alidade is strengthened along its straight side by a flat rib *mm* (Fig. *k*,) upon which a slide can be moved parallel to the scale *BB*, upon which the projection angle runs. To this slide is attached at *g* a slightly projecting vertical socket, in which moves a little cylinder provided at its lower end with a needle and at its upper end with a knob, which cylinder can be moved up and down close along the edge of the footplate. A slight pressure of the finger serves to force the needle down and to mark a point in a paper lying beneath, while upon the removal of the pressure a spiral spring coiled around the socket lifts the needle up again.

By the arm *f*, the slide is connected with the projection angle and it will therefore transfer directly upon the plane-table, in a mechanical way and by means of the needle cylinder, the motions of the projection angle, which correspond in the proportion shown to the horizontal dis-



TACHYGRAPHOMETER
OR
PLANE-TABLE TACHYMETER.

tance of the point observed, without its being necessary to first read this distance from the vernier *c*. (Figs. *k* and *l*.)

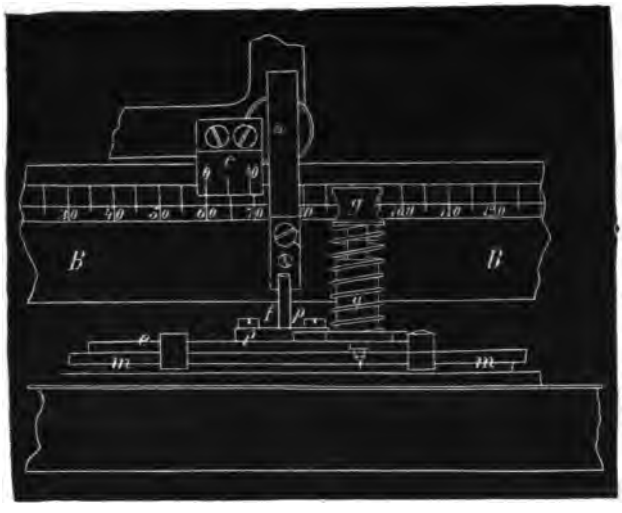


FIG. *k*.

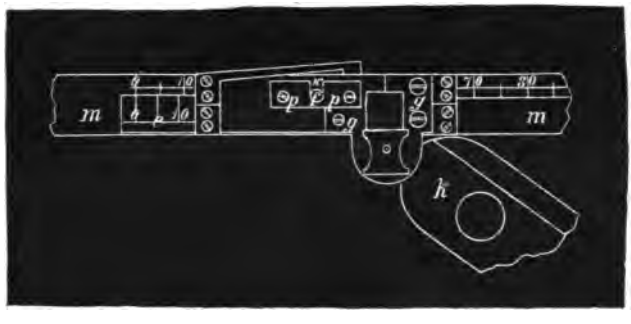


FIG. *l*.

Upon the flat rib *m* there is a scale of distances and upon the slide at *e* is fixed a vernier, which serves for mapping in case the slide should be used independently of the projection angle, for which purpose the arm *f* can then be removed.

This case occurs when it appears desirable to choose the scale of the map smaller or larger than the scale to which the projection apparatus is adapted.

Then the horizontal distances can be read from the vernier *c* and can be set off in corresponding reduction upon the graduation of the rib *m* by the vernier *e*.

In the ordinary use of the instrument, however, the slide remains joined to the projection angle and the graduations of the rule *B B* and of the rib *m m* do not then come into use.

SEC. 22. In order to be able to practically make use of the above process of transforming horizontal distance in graphical delineation, it is, however, necessary, in the first place, that during the observations the alidade should turn exactly about the station point marked upon the table, and that, secondly, the needle cylinder should coincide with this station point when the vernier *e* stands at zero upon the scale of distance, or, if mapping mechanically, the projection angle should stand with its forward edge in the produced axis of the telescope.

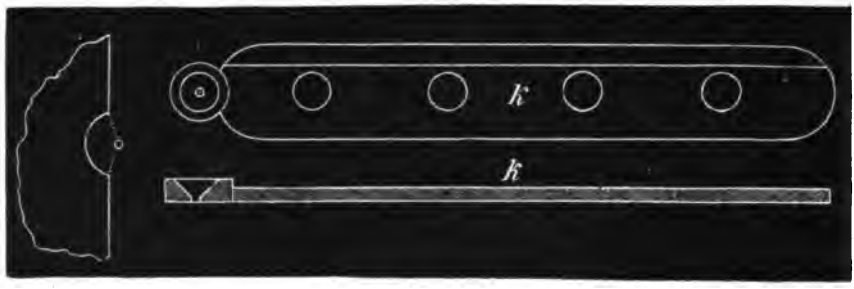


FIG. *m*.

This is accomplished by the aid of a small centering rule *k* (Fig. *m*), whose circular end can be placed over any desired point by means of a little hole at its center. In the straight edge of the alidade rule a circular segment is cut out, the radius of which is exactly equal to the radius of the outer circumference of the end of the centering rule, and with the middle point of which the needle of the cylinder would coincide in the before-mentioned position of the slide.

If we place the head of the centering rule exactly in the opening in the alidade rule, then the middle point of the opening must coincide with the middle of the small hole, and in order to satisfy the requirements of graphic delineation it is only necessary to move both parts until the station marked on the table lies in the middle of the peep hole.

Then the centering rule is held fast with the right hand, while the left hand makes the necessary rotation of the alidade, which motion is very readily accomplished, in consequence of the radial arrangement, with reference to the center of rotation of the relieving rollers mentioned in section 20.

SEC. 23. In plane-table surveys, as is well known, the horizontal angles which the lines of sight make with the line of orientation are transferred directly from the ground to the map fastened upon the table; yet heretofore it was necessary to plot horizontal distances, determined in any manner, by compass and scale along the straight edge of the rule.

But with the above-described mapping apparatus the latter work is avoided, and all the mapping is accomplished in a purely mechanical way without the necessity of any manipulation other than the pressing down of the needle cy inder.

On the Wagner-Fennel Tachymeter and Tachygraphometer.

The concentric setting of the center over the station has properly only to be done once for each position of the instrument, while with some practice it is so quickly done that a frequent renewal of the setting is not a matter of great moment.

The plotting therefore without detriment to a more than satisfactory exactness takes up so little time that it may properly be regarded as the immediate result of the surveying operations.

SEC. 24. The fastening of the paper to the plane table might be accomplished in the usual and well-known manner.

But since in land surveys for the purpose of studying locations a long and narrow zone is generally to be considered, two rollers are attached below the plane table for surveys on long pieces of paper.

In order to increase the adaptability of the instrument, it is so arranged that the alidade can be fastened directly upon the movement. For this purpose three milled-head screws are furnished with the instrument, which pass through adjusting nuts and have corresponding hollow threads in the base of the alidade. (Fig. *n*.)

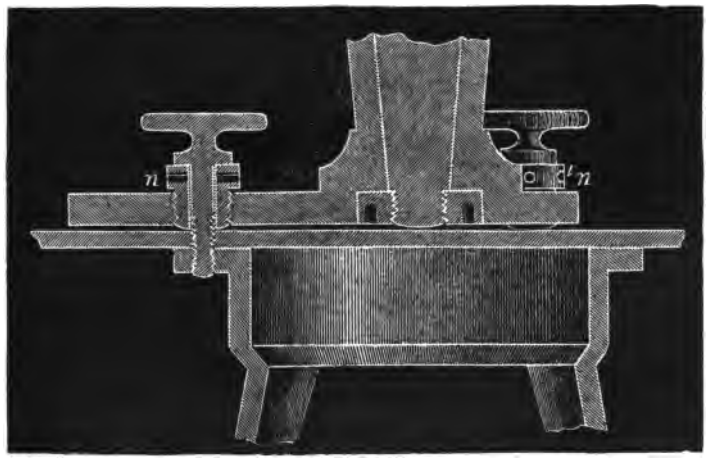


FIG. *n*.

Before the alidade is placed upon the movement and the three above-described screws are tightened, the ivory relieving rollers of the alidade should be screwed up high, so as not to project below the base plate. Then the instrument may be used for leveling, as well as for angular measurements, for which purposes the telescope is provided with a reversion level, and the movement with a horizontal circle whose opposite verniers read to single minutes.

The limb and the verniers lie in one plane inclined to the sight, in order to be conveniently read in any position of the foot plate.

SEC. 25. The use of the instrument is sufficiently obvious from what has already been said, but the following will be repeated:

The setting of the stand over the desired point on the ground, and the leveling and orienting of the plane table, are accomplished according to the regular rules for plane-table work. Then the height of the station above the datum plane is set upon the scale of heights of the projection angle, the relieving rollers are put into action, without, of course, throwing the alidade out of level, and finally the center of motion of the alidade is brought by means of the centering rule over the point on the map corresponding to the station on the ground.

The setting of the tachygraphometer is now complete and the survey proper can be proceeded with, in which for each point to be plotted the following manipulations are to be followed in the order stated:

(*a*) The telescope is pointed to the telemeter held at the desired point and the distance (on the slope) is read off.

(*b*) The slide upon the upper rule *A A* is set by the vernier *b* to this distance.

(*c*) The projection angle is pushed against the vernier *a*.

(*d*) The needle cylinder is pressed down, and—

(*e*) By means of the vernier *a* the height of the distant point is read off and marked at the point plotted upon the map.

Only five separate manipulations are therefore necessary, two of which, however (*c* and *d*), are mere motions of the hand and therefore require no particular attention.

ON HOLDING THE TELEMETER AT RIGHT ANGLES TO THE LINE OF SIGHT.

SEC. 32. The rods which are furnished with these instruments are 4·5 metres long and are graduated on both sides. One side is arranged for measuring distances, and at the height of 1·5 metres it has a special sighting mark, which is the zero point of the scale. The other side is intended for leveling, and has, therefore, a uniformly continuous graduation and numbering, the zero point of which coincides with the foot of the rod. For convenience of transportation, the rod slides together to a length of 1·75 metres.

The correctness of the reading of distances from the rod held at right angles to the line of sight will depend upon its being held correctly and steadily. The observer can readily test whether the rod is held right, since the sighting-blocks, whose upper edges are pointed towards the instruments, are painted black in front, and white above and below. (Fig. *o*.) In the correct position of the rod the observer can see only black surfaces, but if the rod is badly held, a white strip will be seen above or below, whose width will correspond with the amount of error in holding the rod. In this way the holding of the rod is accurately tested when one is in position to read the distance.

On the Wagner-Fennel Tachymeter and Tachygraphometer.

The following method of setting the rod has been found convenient: First, direct one of the edges of the sighting-block upon the instrument, and then bring the bubble of the transverse level to the center, any slight deviation of the edge of the block from the line of sight being at the same time corrected.

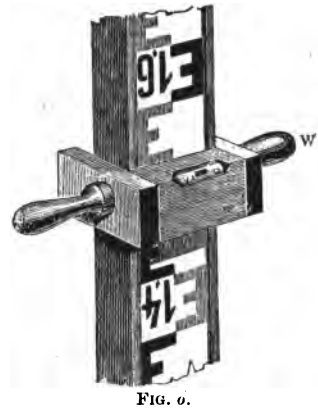


FIG. 6.

In training a rodman, he should be required to stand exactly behind the rod and to sight directly at the instrument without twisting his neck, his eyes being about 40 or 50 centimetres from the rod and his arms extended nearly to their full length. In this exact setting the slight angular motion necessary for bringing the level bubble to the center is involuntarily made approximately at right angles to the line of sight, so that the sighting-block is not noticeably, if at all, deflected from the line of sight.

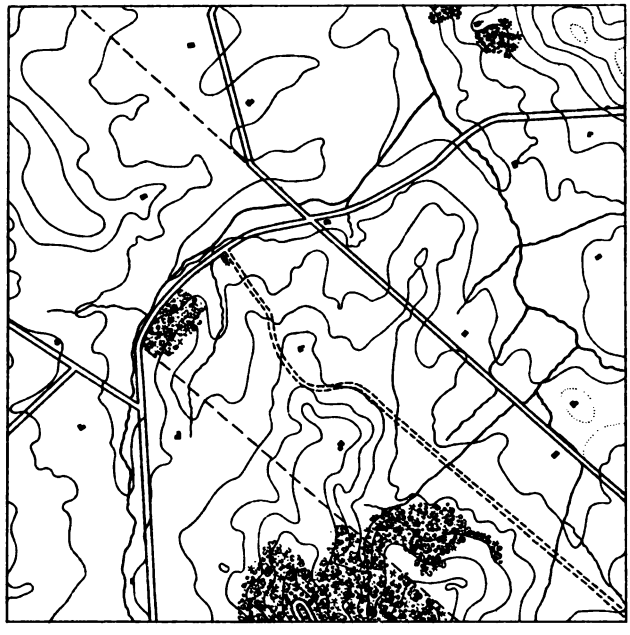
In windy weather it is advisable to use a light brace about 2 centimetres in diameter and 1·70 metres long as a help. This is planted about one-half or three-fourths of a metre from the rod, on the side opposite the wind, and inclined so that the upper end passes behind the handle, to which it is firmly held by the fingers, the thumb holding the brace. While setting the rod in position the brace is held loosely, and is brought into play only when the rod has been correctly placed. A rodman who is not very strong should always carry such a staff, especially as it causes no material loss of time. The rod must be set correctly each time in from three to five seconds, at the longest.

SUPPLEMENT N.

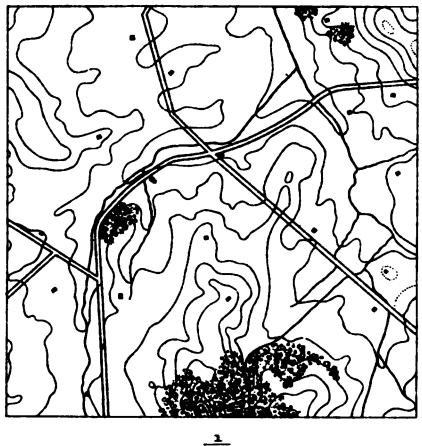
REDUCTIONS UPON DIFFERENT SCALES.

REDUCTIONS FROM THE SCALE OF 1-4800.

A part of the topographical survey of the District of Columbia, illustrating the power of different scales for the delineation of topographical features, is shown on illustration No. 34. Contour interval of the original District of Columbia survey, 5 feet; contour interval of the reductions, 20 feet; reductions made under the direction of Assistant John W. Donn.



$\frac{1}{20\,000}$



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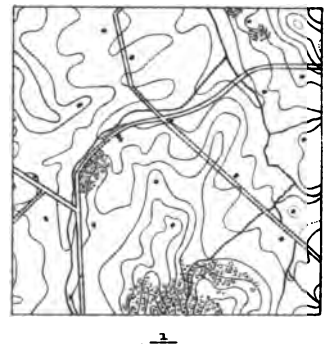

$\frac{1}{40\,000}$

Reductions on different Scales

Contour interval 20 ft.